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QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES

FLORIDA SCIENTIST

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QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES

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Environmental Sciences

LIMNOLOGY OF AN ALLIGATOR POND IN SOUTH FLORIDA

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ABSTRACT: *Alligator ponds or gator holes are ecologically important components of the marshes and swamps of southern Florida. Pond limnology was strongly influenced by southern Florida's subtropical environment and its alternating wet and dry seasons. Three morphological types of alligator ponds, peatland, rockland, and cypress ponds, are maintained by the activities of the American alligator. The study pond included emergent and submerged plant zones and was surrounded by swamp and marsh plant communities, particularly cypress swamps. Temperature varied seasonally and was strongly influenced by seasonal plant growth that inhibited mixing and resulted in temperaure differentials equivalent to 12 C/m. The water was relatively clear and slightly brown. Physicochemical characteristics varied seasonally being affected by concentration in the dry season, dilution n the wet season, and the effects of fish kills. Oxygen supersaturation was frequent and diurnal fluctuation was great, particularly in the dry season. Low dissolved oxygen, high community respiraion, and high fish densities caused fish kills. Reserve pH was consistently 8.2-8.3 and* in situ *pH was usually 7.1-7.8. The water was highly buffered; total alkalinity generally was 130-200 ppm. Nutrient concentrations were generally low. Specific conductance usually ranged 184-290 μmho/cm². Most constituents reached extreme levels during a fish kill. Although remote, the pond showed evidence of pesticide contamination.*°

ALLIGATOR PONDS or "gator holes" are important features of the wetland ecosystems of southern Florida. These shallow ponds exist in a subtropical nvironment characterized by seasonal fluctuation of water level and yearly variation in total rainfall. They provide low-water refugia for aquatic organisms nd concentrated food sources for mobile predators (Kushlan, 1974a, 1976). Despite their ecological importance, little is known about the limnology of alligator ponds.

In this paper we discuss certain aspects of the descriptive limnology of an lligator pond in the Big Cypress Swamp of southern Florida. The study was

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°The costs of publication of this article were defrayed in part by the payment of charges from funds made vailable in support of the research which is the subject of this article. In accordance with 18 U.S.C. § 1734, is article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

conducted from 1969 to 1973. The pond was studied intensively from 1969 to 1971 by Kushlan. Some aspects of this study have been presented elsewhere (Kushlan, 1973, 1974a, b, 1976; McPherson, 1969, 1970). Chemical and physical sampling was continued in 1971, 1972, and 1973 under the direction of Hunt.

METHODS—Water levels were measured by standard U.S. Geological Survey staff gauges permanently positioned in the pond but not corrected to mean sea level. Water level data were also collected at U.S. Geological Survey gauging station, Bridge 105, where water level fluctuations closely reflected conditions at the pond 13 km to the southeast. Rainfall and evaporation were measured at the U.S. Weather Service station at 40-mile Bend Ranger Station.

Chemical and physical data were obtained intermittently from April 1969 to April 1973. Two complete chemical samples were taken and processed by Benjamin F. McPherson of the United States Geological Survey in 1969. Samples were taken frequently by Kushlan in 1970, especially from 5 May to 20 August 1970 incident to and following a severe fish kill of 14-24 May. Samples were taken monthly from 30 October 1971 to 8 April 1972 by Paul Evans, and sampling from 23 October 1972 to 19 April 1973 was carried out by Timothy Graham, Kenneth Kirsner and Jimmy Walker, all under Hunt's direction.

Physio-chemical determinations followed standard procedures. Most chemical analyses were performed according to the procedures of the Hach Chemical Company with the Hach Engineering Kit colorimeter except for the following: dissolved oxygen, the Rideal-Stewart modified Winkler method (Welch, 1948); carbon dioxide (Welch, 1948); chloride, Mohr method (A.P.H.A., 1965); pH and reserve pH, Hellige color comparator; conductivity, YSI model 31 conductivity bridge; hardness (Mackereth, 1963); total phosphate, treated by persulfate oxidation (Menzel and Corwin, 1965); and total organic matter (Gonyea and Hunt, 1970). Dissolved inorganic phosphate samples were filtered through a 0.45μ millipore filter.

STUDY SITE—The pond is located in the southeastern part of the Big Cypress Swamp (lat 25°44′50″N., long 80°56′50″W.) (Fig. 1). At the time of the study the pond was owned by the University of Miami and is now part of the Big Cypress National Preserve. In 1970, it had a surface area of 1520 m^2 and a high water volume of 1240 m^3.

The pond included 2 plant zones. As of 1970, the emergent zone occupied 75% of the total surface area. *Panicum hemitomon* amd *P. paludivagum* were the dominant species. From late summer to spring, the central area of the pond was occupied by a dense growth of submerged plants, primarily the naiad, *Najas flexilis*, with some yellow bladderwort (*Utricularia foliosa*).

Four plant communities occur near the pond: hammock forest, cypress swamp, hardwood swamp, and marsh prairie (Fig. 2). The hammock forest grows on an island of limestone outcropping above high water level. Near the pond this community was dominated by plants of West Indian affinity including *Coccoloba diversifolia*, *Nectandra coriacea*, *Bursera simaruba*, *Ficus aurea*, and *Psychotria undata*. Trees of temperate affinity especially *Quercus virginiana* and *Q. lauri-*

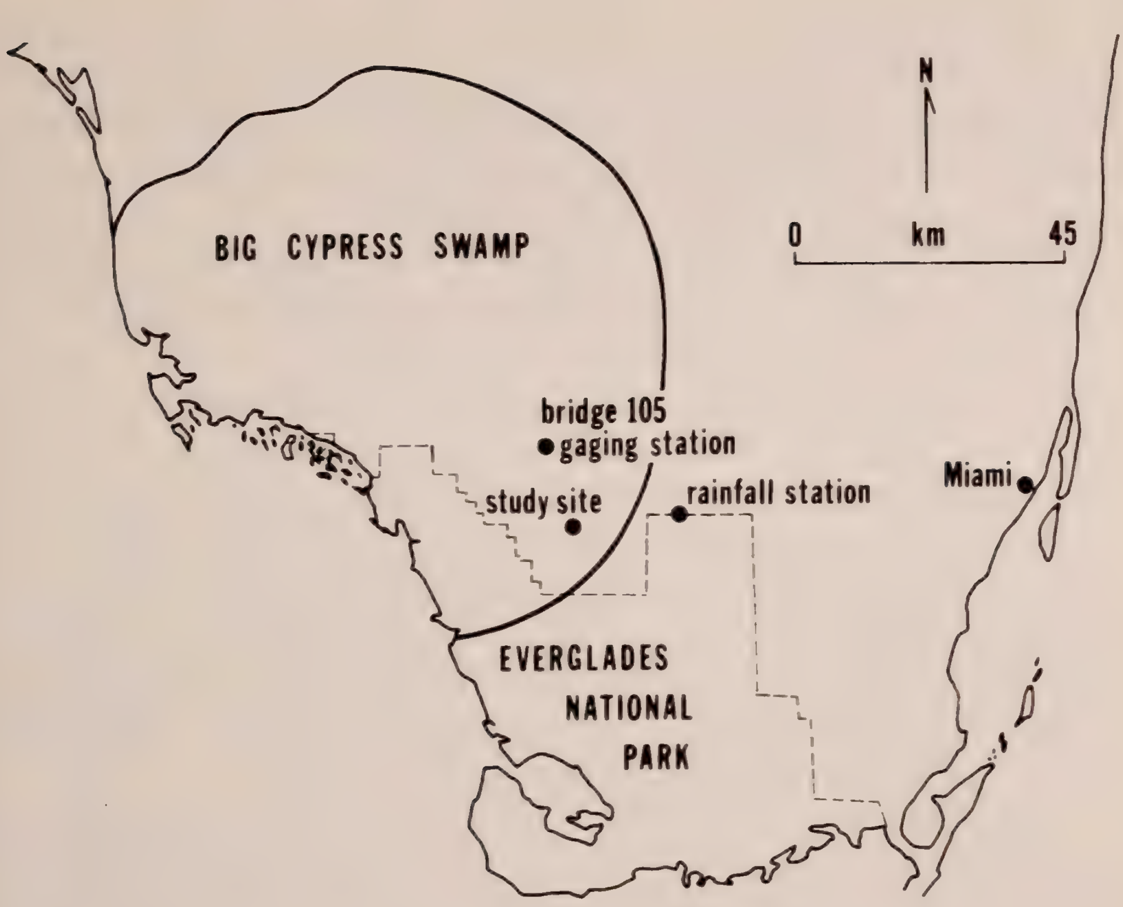

FIG. 1. Map of south Florida.

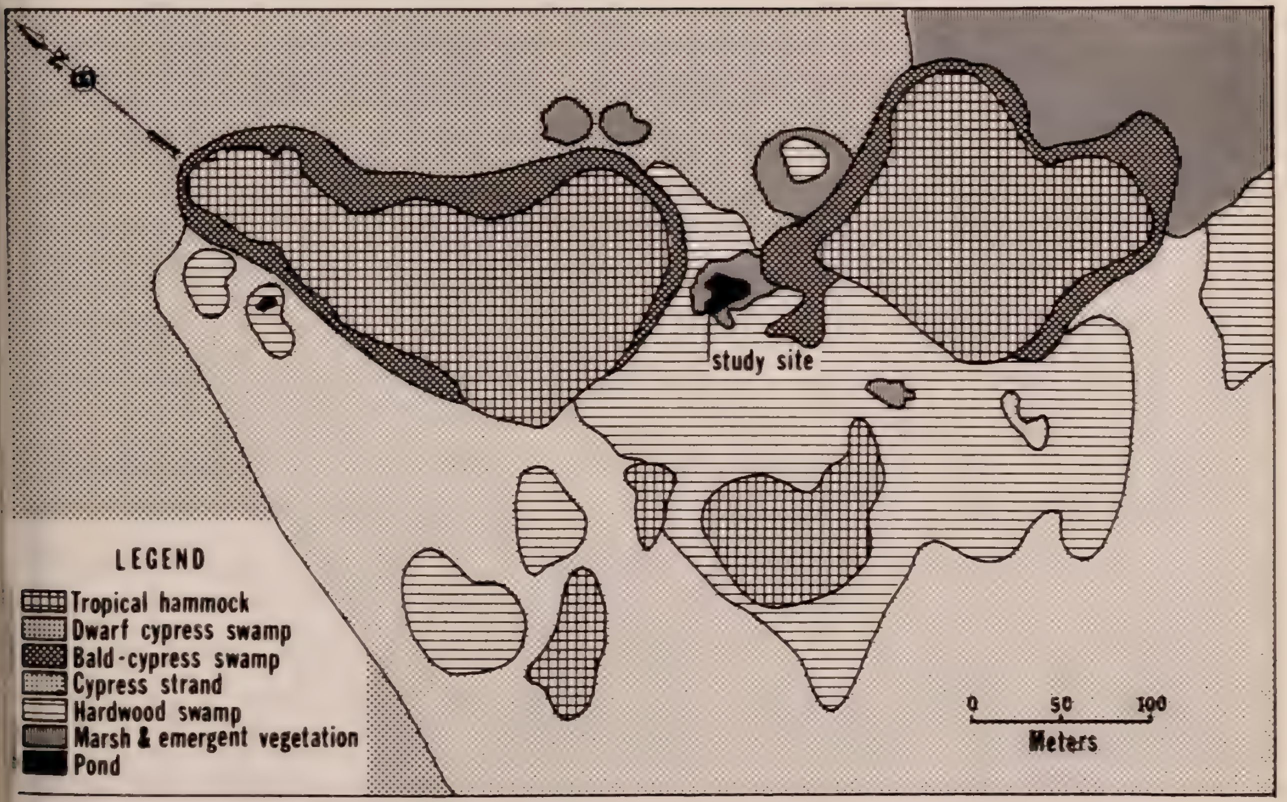

FIG. 2. Plant communities near the study site.

folia occur as well. Epiphytes include *Tillandsia usneoides*, *T. fasciculata*, and *Microgramma heterophylla*.

Three fairly distinct types of cypress swamp are also located near the pond. Dwarf cypress swamp, the most extensive community near the study site, is dominated by thin and widely spaced pond-cypress trees (*Taxodium distichum* var. *nutans*) few of which exceed 5 m in height. Soil is less than 15 cm deep. Epiphytes are common, including *Tillandsia usneoides* and *Encyclia tampensis*. Sawgrass (*Cladium jamaicense*) is the most abundant species of the herbaceous stratum. A mat of periphyton several centimeters thick covers most of the swamp bottom.

The dominant tree of the bald cypress swamp is *Taxodium distichum*, which reached a height of 20 m. These stands occupy a depression in the bedrock along the periphery of the tree islands. Soil is as much as 1 m deep. *Annona glabra*, *Fraxinus caroliniana*, and *Cephalanthus occidentalis* form a second stratum. Epiphytic plants were abundant, including *Psilotum nudum*. Submerged and emergent plants include *Crinum americanum*, *Saururus cernuus*, and *Bacopa caroliniana*. This swamp was severely damaged by intense fires during the spring of 1971. Root burning caused the toppling of many old trees, and thereafter the epiphytic community decreased markedly.

The third type of cypress swamp occurred southwest of the pond. This stand was in many respects intermediate between dwarf cypress and bald-cypress swamps. The trees were larger with more epiphytes. This stand, approximately 1 km wide, formed downstream of the tree island (Fig. 2) and extended to the southwest forming Gum Slough, which drains towards the Gulf of Mexico.

Hardwood swamps included a willow-head located northeast of the study pond. This distinct community of *Salix caroliniana* occupies a depression in the bedrock and may be a former pond. Willows bordered the study pond except on the southern and eastern edges at the time of the study. South of the pond is a hardwood swamp dominated by *Anona glabra* and *Fraxinus caroliniana*. Both *F. caroliniana* and *A. glabra*, primarily the former, make up most of the dense hardwood swamp southwest of the pond.

Several stands of marsh vegetation occur near the pond. These marsh prairies occupy deep basins and are covered during most of the year by up to 1 m of water. They are composed of several distinct stands of marsh vegetation. The dominant plants are *Eleocharis cellulosa*, *Pontederia lanceolata*, *Sagittaria lancifolia*, *Cladium jamaicense*, *Typha* sp., and *Thalia genticulata*.

HYDROLOGY—Annual rainfall at the study site averages 1350 mm/year; 81% of the rain fell from May to October (Fig. 3). Evaporation was highest in the spring and summer (Fig. 3). During the dry season (November to April) evaporation exceeds rainfall, and water levels and surface flow decline. Because water in the study pond is derived from both local rainfall and surface water flow, water levels fluctuated markedly during the alternating periods of rainfall and drought (Fig. 4).

Surface drainage into the pond is from the Big Cypress Swamp to the north. Surface flow in this region of the Big Cypress is constricted by culverts as it asses under U.S. Highway 41 (Fig. 1). At the time of the study the area was onsidered to have been little altered from natural conditions (Klein et al., 970; Leach et al., 1972).

MORPHOMETRY—Based upon morphometry, alligator ponds in southern lorida are broadly divisible into 3 types: cypress ponds, rockland ponds, and eatland ponds. Most cypress ponds occur in the Big Cypress Swamp. They re large (up to 200 m in diameter), often bordered by cypress, and relatively eep (up to 4 m). These ponds occupy depressions in the underlying limestone hat were probably formed by subaerial solution when sea level was lower. he basin is overlain by a sedimentary deposit of organic mud that is extremely loculent in its top 30 cm. The study site represents this type of pond. The

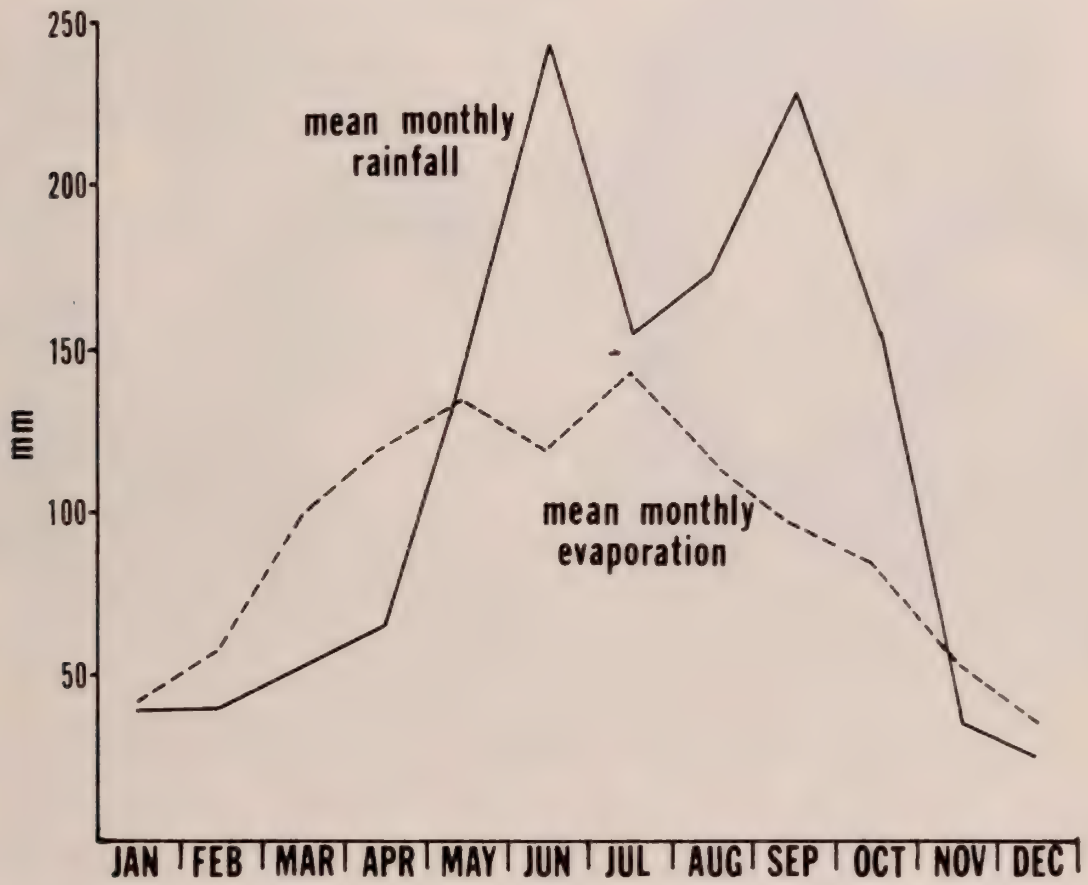

FIG. 3. Mean monthly rainfall (1940-70) and evaporation (1960-69) near the study site.

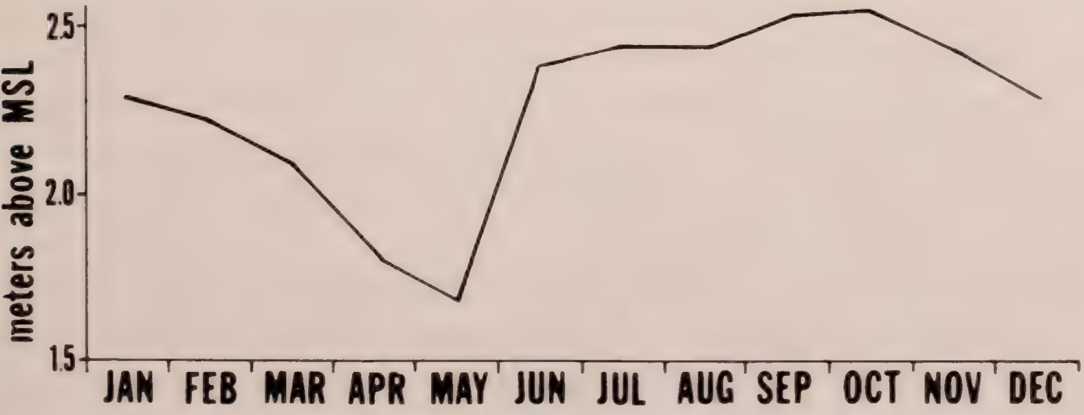

FIG. 4. Average monthly water level (1962-1972) at gauging station Bridge 105 near the study te.

morphometry of the study pond basin is irregular and shows two sub-basins, one deeper than the other (Fig. 5). There is little correlation between basin morphometry and the location of plant zones. The sedimentary deposit varies 30-225 cm in depth, being thickest over the deepest parts of the basin (Fig. 6). The pond is generally deeper in the central plant zone and shallower in the peripheral emergent zone (Fig. 5). This is especially evident in certain locations where there was a 60 cm dropoff at the interface of the submerged and emergent plant zones. In other areas the difference in depth between zones is less.

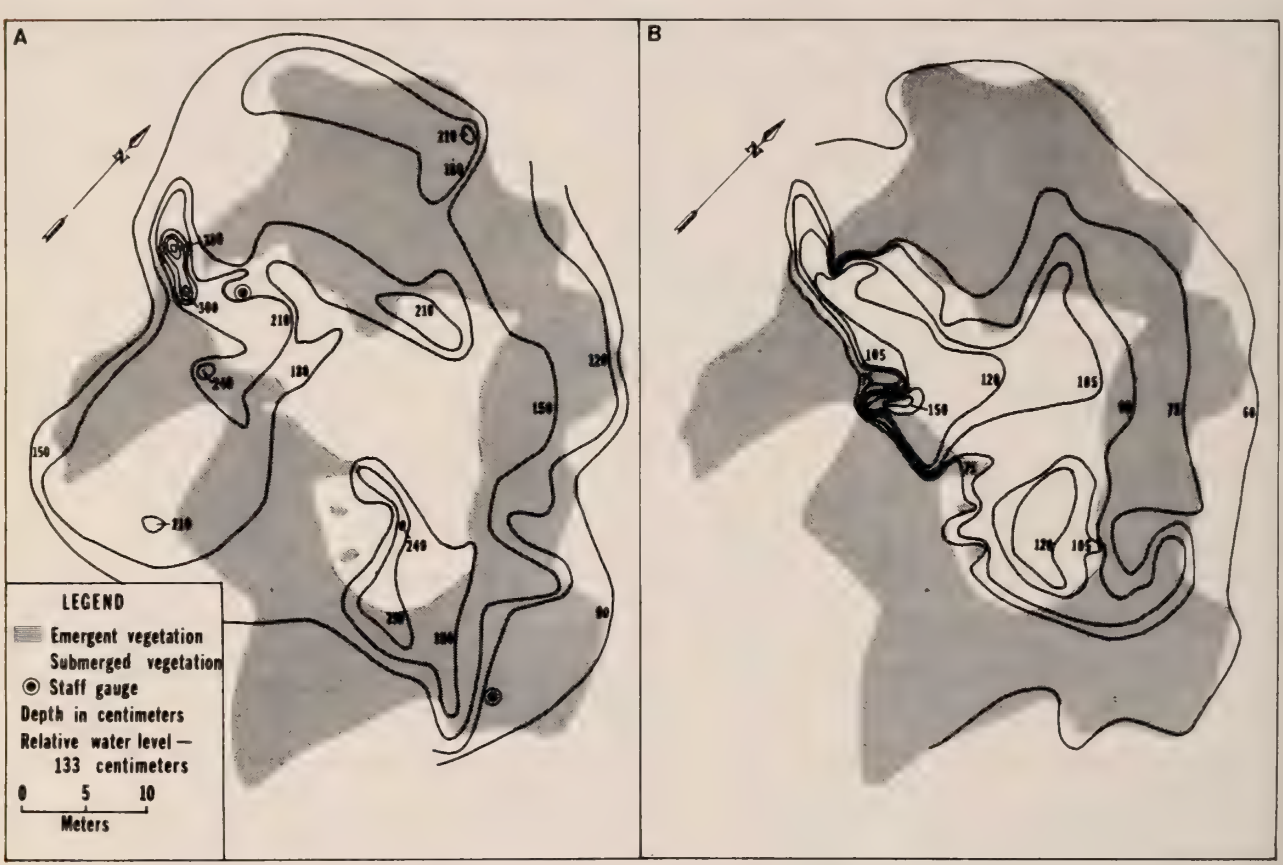

FIG. 5. Bathymetry (A) and morphometry (B) of the study pond in 1970. Depth contours are in cm. Dark shading represents emergent plant zone. Light shading represents submerged plant zone.

It is useful to compare cypress ponds such as the one studied, with other types of ponds. Rockland ponds are found throughout the southern Everglades. They differ from cypress ponds by being smaller, shallower, and lacking cypress trees. They are common throughout the Everglades marsh. Like cypress ponds, these ponds occupy basins in the underlying limestone, and the sedimentary deposit is an organic mud. These ponds usually have a sloping bottom with the deepest part of the basin and the deepest part of the pond coinciding near the center (Fig. 6). In some cases sediment may be lacking in the center, and the rock bottom may be visible.

Peatland ponds are holes in thick peat. Morphometry of the pond shows no relation to the underlying bedrock, as it occupies a pocket within the thick peat sediment (Fig. 6). The sedimentary deposit is highly organic and compact. Such ponds may form when fire causes a localized burnout of the peat to considerable depths, an origin similar to ponds in the Okeefenokee Swamp (Cypert,

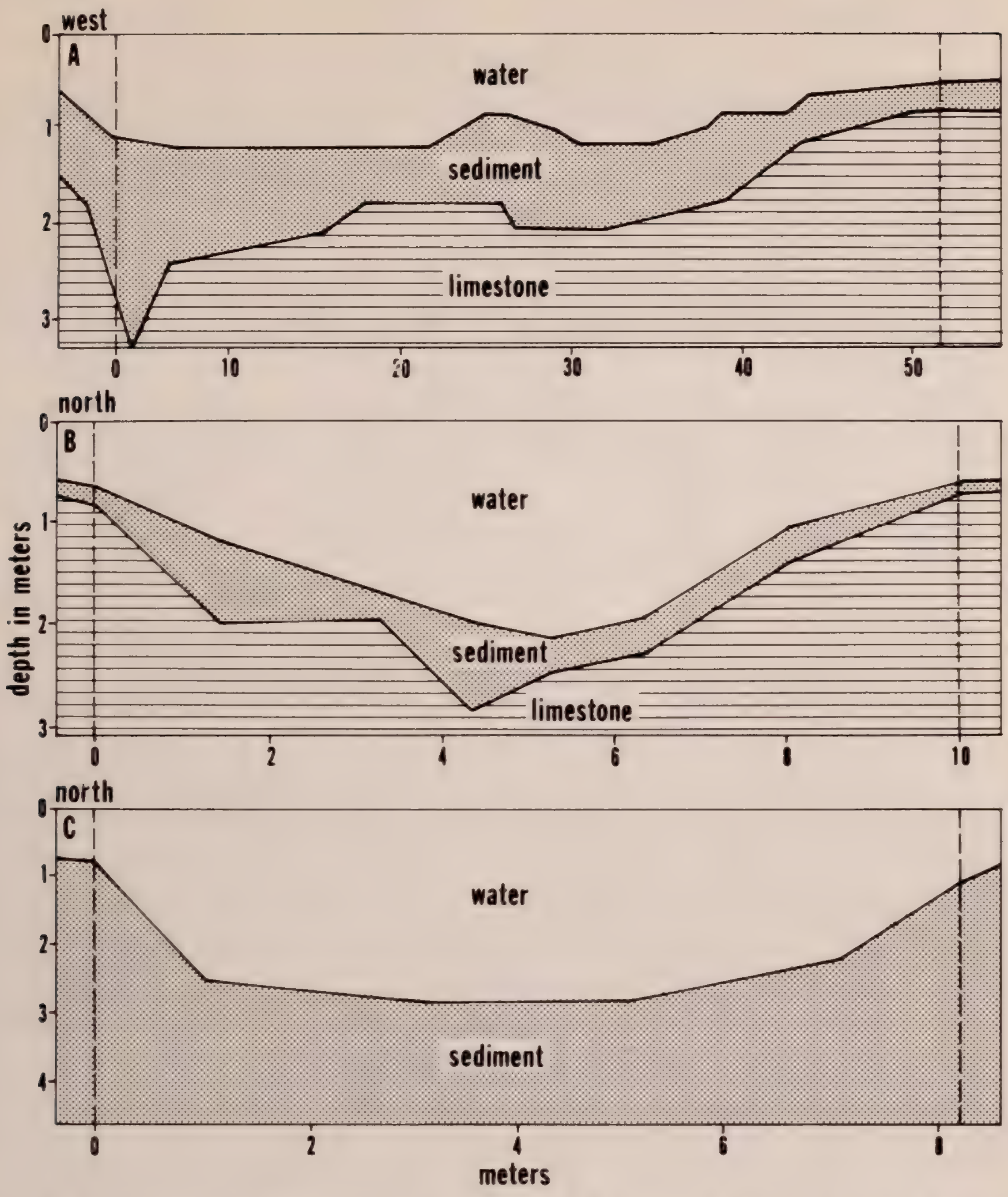

Fig. 6. Representative morphometric transects of 3 types of alligator ponds. Top: cypress pond (study pond). Center: rockland pond. Bottom: peatland pond. Vertical scales exaggerated; vertical dotted lines indicate edge of the pond as determined by plant zonation.

1961). Peatland ponds are characteristic of the northern Everglades, but are also found in wet prairies in the Big Cypress Swamp.

Ponds of all types are maintained by the American alligator (*Alligator mississippiensis*) (Kushlan, 1974a). The alligator's activity arrests hydrarch succession by maintaining pond depth and inhibiting encroachment by both peripheral emergent plants and open water submerged plants. It does this by digging, especially in the dry season, and by day-to-day movements that uproot plants. Droughts encourage the encroachment of rooted plants in drying ponds by permitting seedling establishment and rhizome sprouting; the alligator's activity at this time is especially important. Thus, the existence of ponds and their morphometry depend on the presence of alligators and on maintenance of water levels (Kushlan, 1974a).

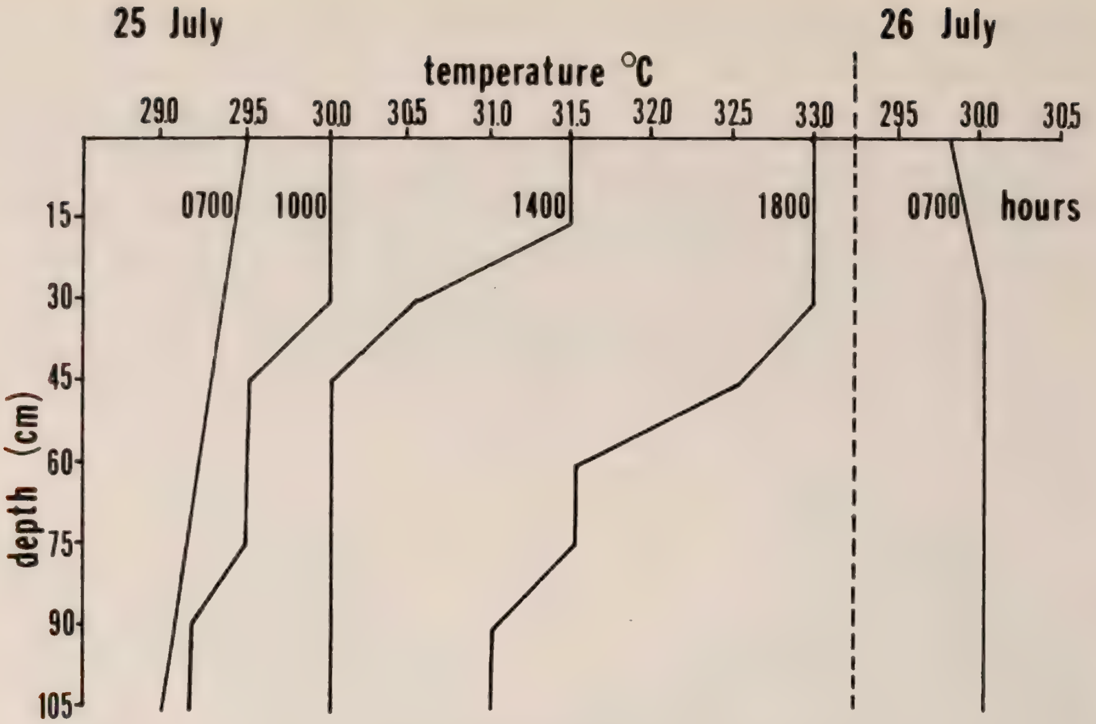

FIG. 7. Variation in the vertical temperature profile of the pond on 25-26 July 1970.

TEMPERATURE—Although the alligator pond is relatively shallow, water temperature was seldom uniform from surface to bottom (Fig. 7). Heating was primarily from the surface and apparently lacked any contribution by bottom absorption or convection. A decided lag in heating existed in the deeper water even though the depth at the sampling site was only 1 m. As expected, surface temperature fluctuated more than that of the bottom (3.5 C as compared to 2.0 C in Fig. 7). Characteristically, the total diurnal variation was not great. Even during periods of relatively low temperature, the alligator pond showed significant resistance to cooling over a diurnal period.

Seasonally, water temperature was lowest in November through January (winter) and highest in June through August (summer). Weather and atmospheric conditions are also of considerable importance in determining the thermal character of alligator ponds because the amount of energy impinging on the pond's surface is directly related to the amount of sunlight and therefore to time of day and the amount of overcast. Fig. 8 is a 54-hr series of temperature measurements that demonstrate the effect of atmospheric conditions. The first day of measurement was continuously overcast with heavy precipitation totaling 9.5 cm. Water temperature remained unchanged at 21 C during this time. The second day was rainless but heavily overcast. The temperature reached a maximum of 26 C at an unusually late hour of 2100. The third day was clear and the diurnal temperature variation showed a typical pattern. The densely shaded cypress swamp adjacent to the pond had lower temperatures than did the open pond (Fig. 8).

Vegetation also affected water temperature in the alligator pond (Fig. 9). On 25 July 1970 when little submerged vegetation was present, the temperature profile in the central area had a vertical range of only 2°C. For much of the

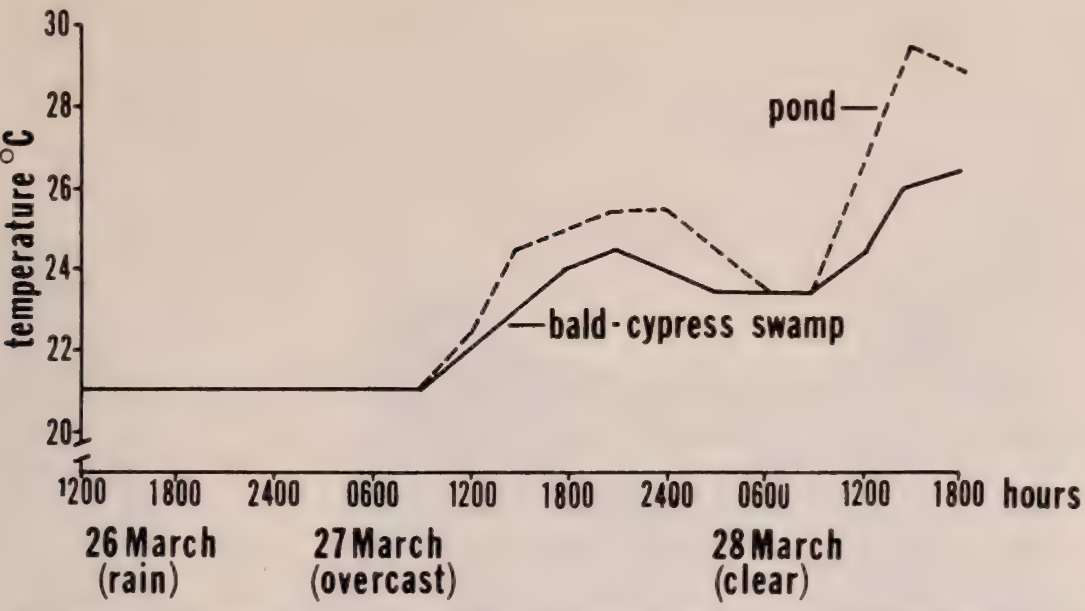

FIG. 8. Variation in water temperature in the pond and in adjacent cypress swamp on succes-ive rainy, overcast, and clear days, 26-28 March 1970.

ear, however, the dense growth of naiad occurring in the central area of the ond had a dampening effect on mixing of the water. On 22 March 1969, when ll but about 10 m^2 of the central area was covered with naiad, there was a verti- al temperature differential of 5 C in only 50 cm of water in the submerged zone. The emergent vegetation also had a significant effect (Fig. 9). Surface tempera- ure was highest at the interface of the emergent and submerged zones. At that oint the vertical temperature differential was 7C in 60 cm of water, equivalent o a thermal gradient of 12 C/m. This temperature differential resulted from he dampening effect of both emergent and submerged vegetation, which de- reased the transfer of radiant energy to the bottom waters. In addition, the ffect of wind was considerably lessened by the pond vegetation and surrounding rees. Lack of mixing had important effects on the distribution of dissolved ases and other chemical constituents.

Physico-chemical Characteristics—Seasonal differences in many of the hemical features were associated with the low water period that normally ccurs in winter and early spring and the high water period of summer and all. Typically many salts and metals were present in greater amounts, because f concentration, during the lower water period and decreased during the wet eason because of dilution. Substances such as dissolved oxygen and free carbon ioxide, as well as pH, that were subject to diurnal change fluctuated widely epending on the density of aquatic plants and on the rates of decomposition nd community metabolism. In a 3 wk period during and following the com- lete fish kill, lasting 14-24 May 1970, the conductivity, turbidity, color, concen- rations of metals and inorganic salts, total hardness, total alkalinity, total organic natter and free carbon dioxide increased greatly. The amounts of these sub- tances tended to return to usual levels about a month after the fish kill.

Because of such fluctuations, it is not always easy to establish a base or usual evel for some of the chemical properties of the pond. Certainly samples taken

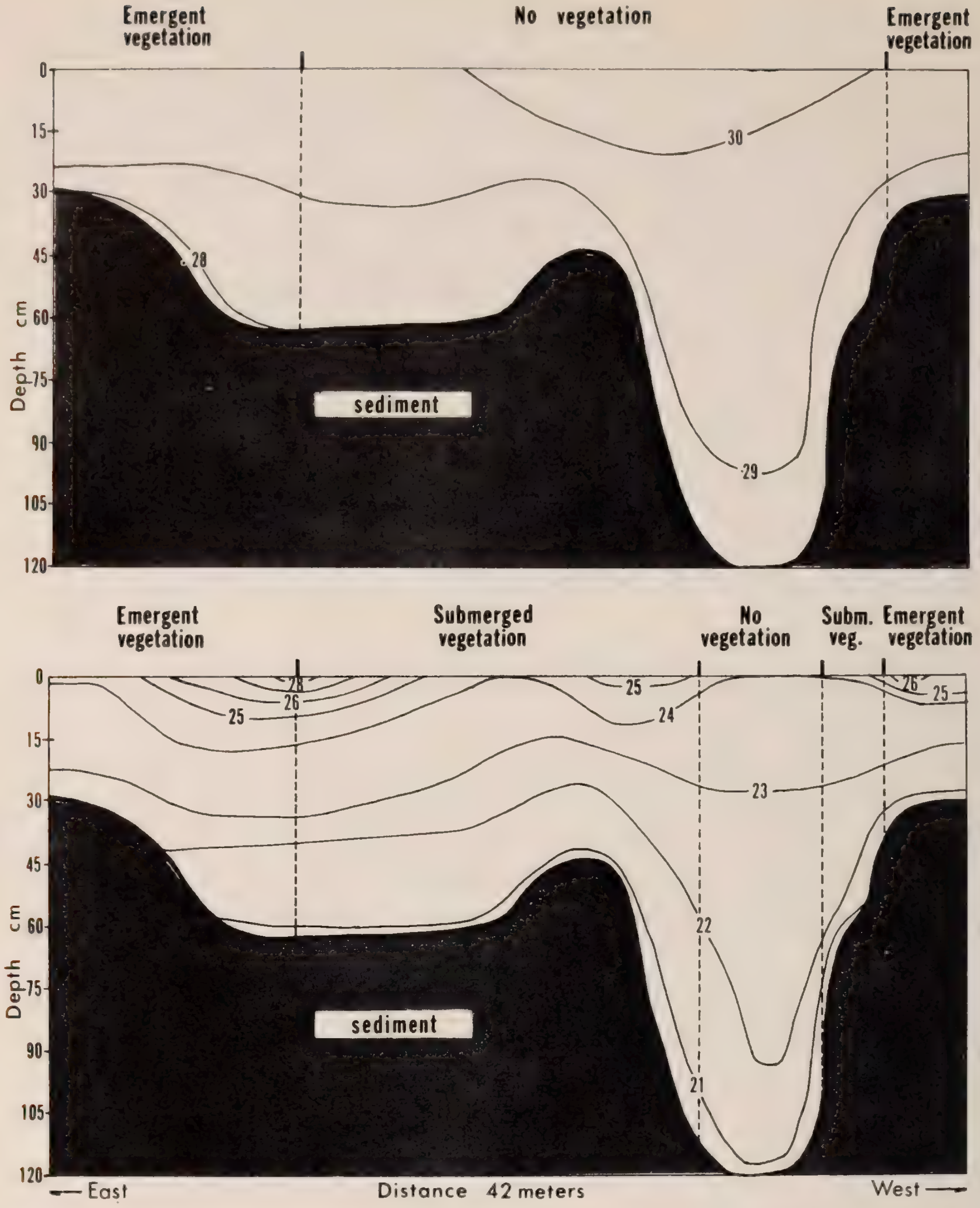

FIG. 9. Thermal contours (C) of the pond on 25 July 1970 when no submerged vegetation was present and 22 March 1969 when submerged vegetation was present.

during the fish kill were unrepresentative of the year round limnological characteristics of the pond. Table 1 shows extensive analyses of pond water that may be taken as representative of the seasonal variation of chemical characteristics of the pond during high and low water.

Dissolved Oxygen: Except for the period of the fish kill, the amount of oxygen measured in surface waters during daytime hours over the 4-yr period ranged 0.39 ppm (5% saturation)-18.6 ppm (214% saturation). Afternoon dissolved oxygen data for 3 widely spaced samples taken at low water levels are in Table 2. The not atypical supersaturation of water is notable. These data show an apparent correlation between high fish densities and low oxygen levels during the dry season. The dissolved oxygen encountered generally ranged from 2-5 ppm, although both higher and lower values were not uncommon.

TABLE 1. Levels of physico-chemical parameters in the pond during low and high water levels. Dashes indicate measurements that were not made.

Item	Low water 22 April 1969	High water 16 July 1969	Low water 11 May 1970
Relative water stage (cm)	89.1	122.1	90.0
Time (hrs)	1530	1300	1500
Water temperature (C)	30	32	30
Turbidity (JTU)	15.0	8.8	5
Color (Pl-Co units)	40	20	20
Oxygen (ppm)	11.60	7.20	3.7
Oxygen (% saturation)	150	97	49
pH	7.8	7.8	7.4
Conductivity (μmho/cm^2 @ 25 C)	400	208	355
Chloride (ppm)	29	11	25
Alkalinity (ppm as H_2CO_3)	180	110	162
Hardness (ppm as $CaCO_3$)	152	92	174
Calcium (ppm)	56	34	62
Magnesium (ppm)	2.9	1.6	4.4
Total dissolved solids (residue @ 180 C)	240	138	–
Total organic matter (ppm)	54	–	16.2
Floride (ppm)	0.2	0.2	–
Iron (ppm)	0.22	0.05	0.0
Potassium (ppm)	1.9	0.6	–
Silica (ppm SiO_2)	2.2	3.2	0.76
Sodium (ppm)	20.0	7.6	–
Strontium (ppm)	–	0.35	–
Sulfate (ppm)	0.8	0.0	–
Tannin, lignin (ppm)	1.0	0.0	–
Nitrate (ppm)	0.1	0.1	0.022
Nitrite (ppm)	0.01	0.01	0.017
Ammonia (ppm)	0.02	0.02	–
Organic nitrogen (ppm)	0.87	0.87	–
Phosphorous (ppm PO_4)	0.08	0.00	0.08
Aluminum (ppm)	0.19	0.07	–
Arsenic (ppm)	0.00	0.01	–
Boron (ppm)	0.05	0.02	–
Bromide (ppm)	0.00	0.00	–
Chromium (ppm)	0.00	0.00	–
Copper (ppm)	0.00	0.01	–
Iodide (ppm)	0.00	0.00	–
Lead (ppm)	0.00	0.00	–
Lithium (ppm)	0.00	0.00	–
Manganese (ppm)	0.00	0.00	–
Zinc (ppm)	0.02	0.01	–
Phenolic material (ppm)	0.003	–	–

TABLE 2. Dissolved oxygen in alligator pond on dates when relative water level was approximately 90 cm.

Date	Sample time (hours)	Water level (cm)	Oxygen (ppm)	Temperature C	% Saturation oxygen	Fish density
22 April 1969	1600	89.1	11.6	30	150	Low
9 May 1970	1400	95.2	4.5	30	59	High
16 December 1970	1500	93.3	14.0	24	169	Low

Most of the oxygen in this pond is produced by photosynthetic activity of phytoplankton, periphyton, and especially submerged aquatic plants. Because of this, as is generally true elsewhere in south Florida, the diurnal fluctuation of dissolved oxygen in this pond was often very great. The maximum amounts present in the afternoon were usually relatively high and the amounts present at daybreak were usually relatively low. On a sunny day in early spring when submerged vegetation was abundant, it was not unusual to find dissolved oxygen increasing from a trace at 0600 hr to 150% saturation or more by 1500 hr. Particularly when naiad was abundant in the alligator pond, high oxygen levels were attained, but great diurnal fluctuations also occurred. At such times the daily minimum was often 1 ppm or less. The 5 highest recorded values of dissolved oxygen in the pond were 18.6 ppm (214% sat.) on 26 February 1972, 15.0 ppm (186% sat.) on 25 January 1971, 14.0 ppm (169% sat.) on 16 December 1970, 13.5 ppm (153% sat.) on 13 February 1972, and 11.6 ppm (150% sat.) on 22 April 1969.

The effects of sunny weather, rain, and very cloudy weather, and concomitant changes in rates of community metabolism and decomposition, on diurnal dissolved oxygen fluctuation were often striking. This is shown in Fig. 10. During heavy rains the diurnal fluctuation was small, reaching only 54% of saturation (3.4 ppm). Overcast days without rainfall and clear days reached progressively higher levels with greater range of fluctuation. Under these conditions the pond became supersaturated for several hours during the day.

When submerged plants were sparse, the diurnal fluctuation often was appreciable even though the maximum and minimum amounts were fairly low. Typical diurnal variation of oxygen with water depth is in Fig. 11. At 0700 hr on 25 July 1970 the dissolved oxygen at the surface in the open water of the pond was 1.55 ppm, and it was only .50 ppm less near the bottom at a depth of 120 cm. Additional measurements during the day revealed that by 1800 hr the oxygen increased to 4.20 ppm at the surface compared to 2.20 ppm at the bottom. At 0700 hr the following day the difference in oxygen at the surface and bottom was again very small. However, the bottom water then had increased to 1.70 ppm from 1.05 ppm 24 hr earlier. At this time, the surface water contained 2.00 ppm of oxygen compared to 1.55 ppm 24 hr earlier, but it had lost 2.20 ppm of dissolved oxygen from the maximum amount present at 1800 hr the day before.

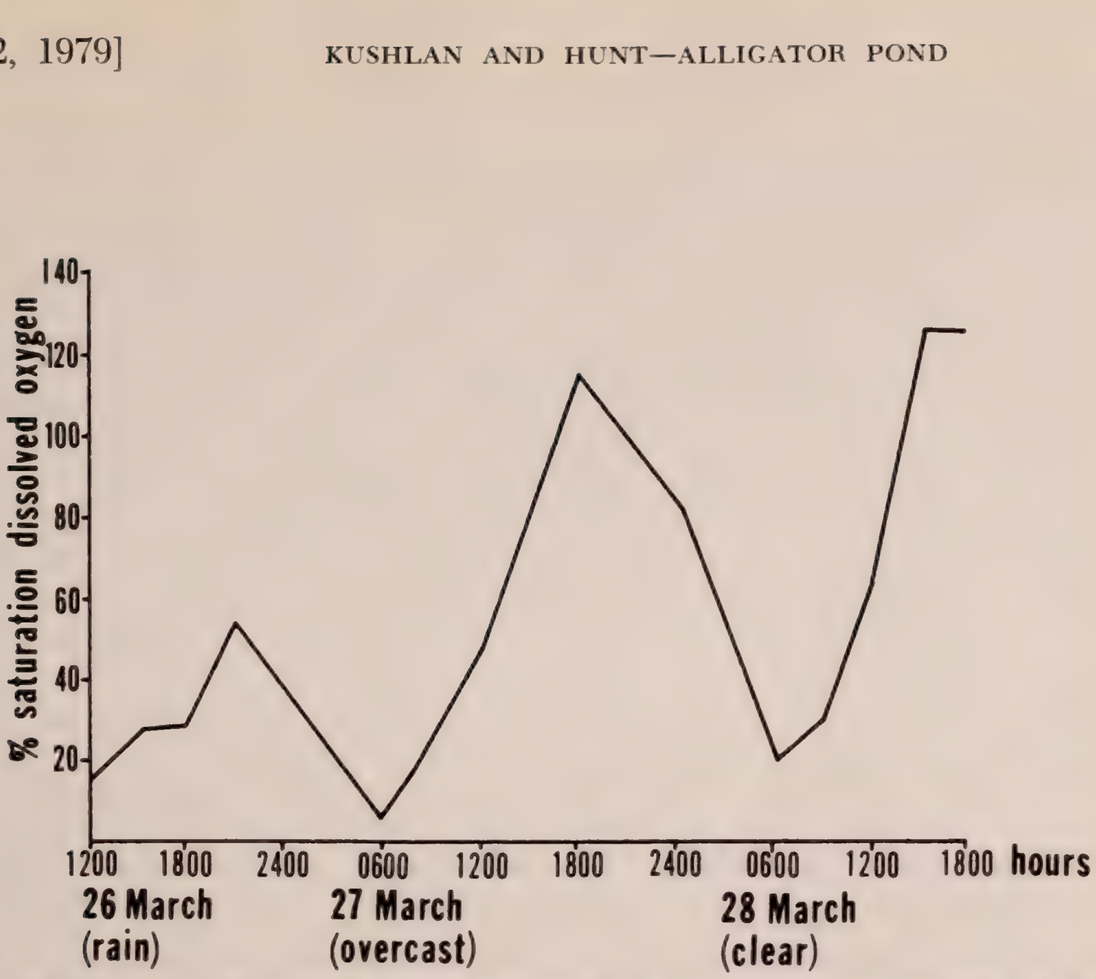

FIG. 10. Variation of dissolved oxygen in the pond on successive rainy, overcast, and clear days, 26-28 March 1970.

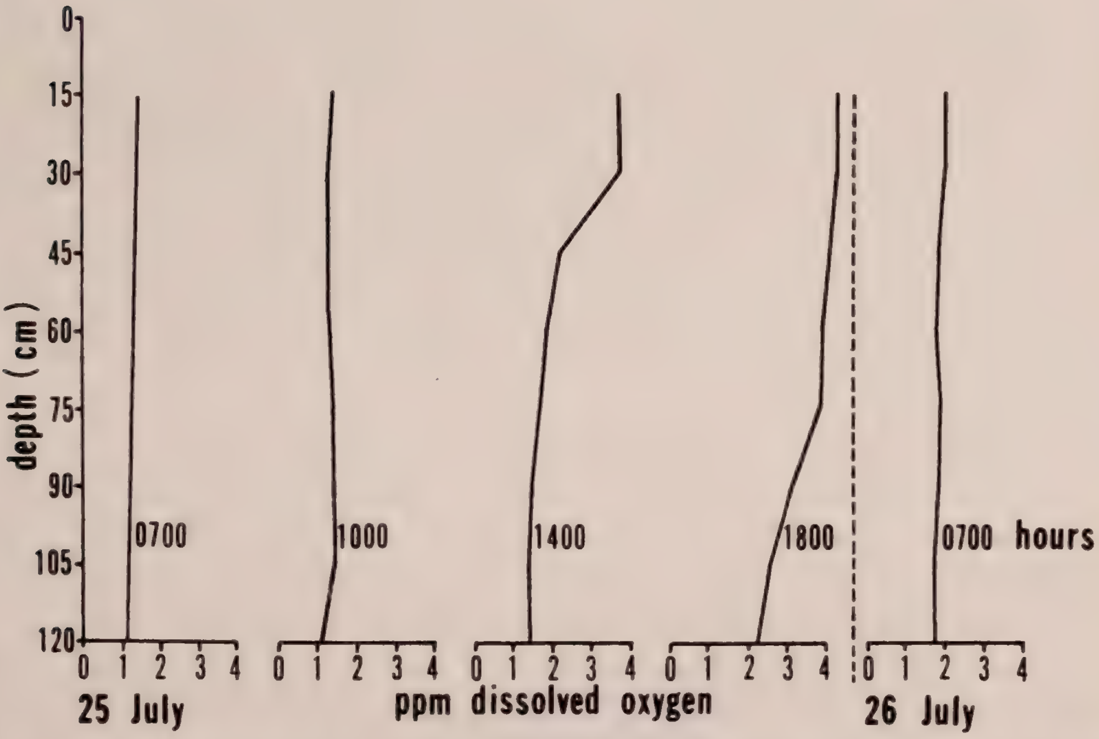

FIG. 11. Diurnal variation of the vertical profile of dissolved oxygen at the pond, 25-26 July 1970.

The fish kill of 14-24 May 1970 was caused by anoxia resulting from a combination of lowering water level, breakdown of the formerly luxurious naiad growth, high densities of fish, high rates of respiration and decomposition, and high water temperature (29-20°C). It was apparent several days before fish began to die that oxygen production was lagging behind oxygen demand and that free carbon dioxide was increasing. Caged fish, including largemouth bass (*Micropterus salmoides*), bluegill (*Lepomis macrochirus*), and spotted sunfish (*L. punctatus*), were placed in the emergent plant zone the night of 5-6 May 1970 and all died, evidence that prolonged anoxic conditions occurred during the night. On 9 May at 1400 hr the oxygen was 2.14 ppm in the emergent plant zone and 4.50 ppm (59% sat.) in the central open water area (Table 3). Three days before the fish kill began the oxygen at 1500 hr was 3.70 ppm at a water temperature of 30 C.

Although the low maximum and minimum oxygen levels during the period preceeding the beginning of fish mortality were within the usual range encountered in the pond, the cumulative stressful effect was such that fish began to die at about 0800 hr on 14 May 1970 and deaths continued until 1100 hr. At 1000 hr on that day dissolved oxygen was 1.3 ppm and the free carbon dioxide was 11.2 ppm. By the end of the day the water mass deeper than about 1 cm of depth was devoid of oxygen, a condition that persisted until 27 May. The distribution of dissolved oxygen between 5 and 21 May is in Table 3. The maximum amounts of oxygen in the open water of the pond before and after the fish kill of 1970 are in Fig. 12.

Free Carbon Dioxide, pH and Total Alkalinity: Free carbon dioxide was usually present in surface waters in amounts ranging from a trace to 19 ppm although quantities most commonly encountered ranged 3-10 ppm. This is a condition similar to many other freshwater environments of south Florida. Considerable variation existed seasonally and diurnally and the quantities of this gas tended to reflect the rates of decomposition and community respiration. Free carbon dioxide was absent only on those few occasions when photosynthetic activity was great enough to utilize all of the free gas present. During the fish kill the very large quantities present in surface water ranged 10.2-37.6 ppm (Table 3) and one sample of water taken from the bottom on 17 May 1970 contained 98 ppm of CO_2.

Measurements of pH were made throughout the study period and thoroughly aerated water samples always gave readings of 8.2-8.3 (reserve pH). The *in situ* pH of the pond waters, largely determined by the considerable amounts of free CO_2 present, was usually 7.1-7.8, although on a few occasions when photosynthetic activity was very great, the scale reading was 8 or above and reached 8.4. Because the water was highly buffered and ordinarily contained appreciable amounts of free CO_2, diurnal changes were usually not great, although on one occasion when a luxuriant growth of naiad was present, the pH changed 7.6 to 8.2 in a period of 4 hr between mid-morning and mid-afternoon. This magnitude of change was not unusual under such conditions and even greater rates of change of pH have been measured for other heavily vegetated waters

TABLE 3. Temperature and concentrations of oxygen and carbon dioxide in pond during May, 1970.

Date:	5 May	9 May		11 May	14 May			15 May		17 May			21 May
Hours:	1400	1000	1400	1400	1000	1500	2000	0500	1100	1100	1400	1900	1400
Emergent zone													
Temperature (°C) –3 cm			29		29	29	28	28	29	30	32	29	
O_2 (ppm)–1 cm								0.24	0.35	0.00	0.20	0.00	
O_2 (ppm)–6 cm			2.14		0.76	0.56	0.00	0.00	0.00	0.00	0.00	0.00	
CO_2 (ppm)–1 cm								17.8		34.6	18.2		
CO_2 (ppm)–6 cm							15.9	23.8		34.6			
Central area													
Temperature (°C) –3 cm	31	28	30	30	29	30	28	28	30	30	32	28	31
O_2 (ppm)–1 cm						3.00	2.20	0.22	0.41	0.05	0.38	0.17	0.50
O_2 (ppm)–6 cm	5.24	2.32	4.50	3.70	1.30	2.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO_2 (ppm)–1 cm								24.7		16.8	10.2	37.6	
CO_2 (ppm)–6 cm					11.2		20.8	32.2		30.0			

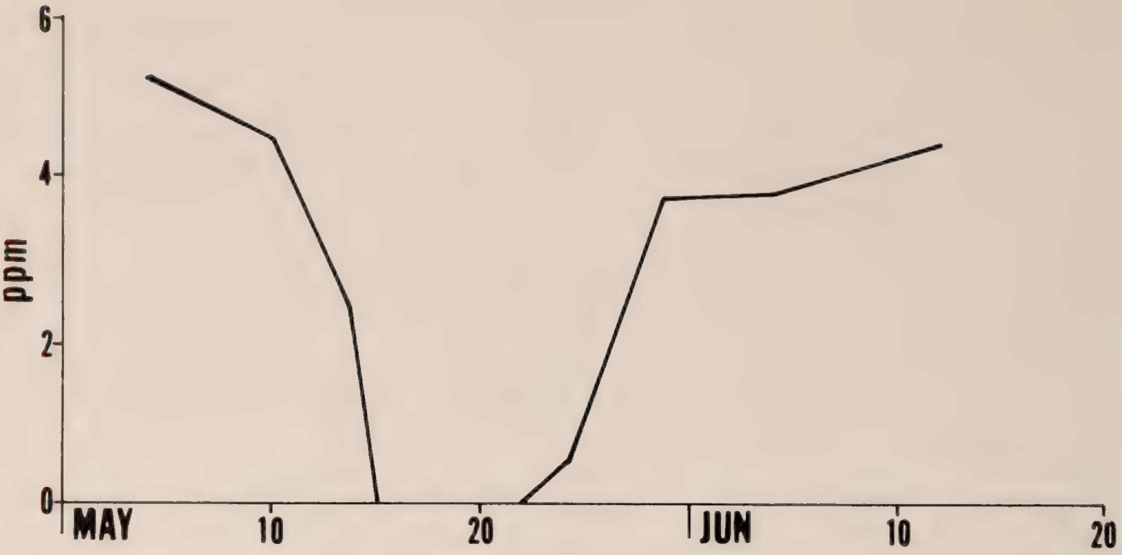

FIG. 12. Fluctuation of dissolved oxygen May-June 1970. All samples were taken at 1400-1500 hr at 6 cm depth.

in south Florida. During the fish kill, when the free carbon dioxide quantities exceeded 30 ppm, the *in situ* pH was as low as 6.6 in surface waters.

Total alkalinity, related as it is to free CO_2 and pH, generally ranged between 130-230 ppm. During most of the sampling period of 1971-72 the values were close to 200 ppm (169-228 ppm). In 1972-73 the values were less (137-214 ppm). In general the total alkalinity was lowest during the high water period of the summer when readings varied from 100-180 ppm and higher during the low water period of late winter and spring when it varied from 180-242 ppm. Changes from one sampling period to another were usually less than 15 ppm but sometimes were as great as 20 to 40 units in one month. During and immediately after the fish kill total alkalinity rose drastically to a maximum of 441 ppm on 21 May 1970. During late May it rapidly declined to 262 ppm. By early June the total alkalinity had dropped to 147 ppm and a slow decline continued into July when a measurement of 89 ppm, the lowest on record, was obtained. Subsequently, the alkalinity began to increase and soon rose to more usual levels above 100 ppm.

Hardness, Calcium and Magnesium: Thirty-eight measurements of EDTA hardness made during the 4 yr ranged 94-235 ppm. The highest value was measured during the latter part of the fish kill period and the lowest of 16 July 1970, 52 days after the fish kill ended. During 1971-73 hardness ranged 142-234 ppm with the highest value occurring on 19 December 1971 and the lowest on 13 January 1973. The amounts usually encountered ranged 150-200 ppm. No obvious seasonal pattern was evident, both high and low amounts were found in winter and spring. However, in general the amounts present during summer when water levels were high were lower than at other times of year. Fluctuations in hardness followed those of total alkalinity rather closely.

Calcium ion concentration ranged 34-86 ppm. Again the highest measurements were during the latter part of the fish kill and the lowest about 2 mo afterwards. From 1971 to 1973, calcium varied 53-83 ppm, with a mean of 71. The fluctuations of calcium were directly correlated with EDTA hardness.

Magnesium was measured in 1969 and from 1970 to early 1971, the amounts ranging 1.60-5.12 ppm, with a mean of 3.40. The greatest amounts were found during the latter part of the fish kill period and the lowest about 2 mo afterwards.

Calcium-magnesium ratios ranged 14.1-26.3 ppm with an average of 18.1. The highest values occurred in May 1970 immediately following the fish kill and the lowest just before and in July following that event. No distinct seasonal pattern in the relative amounts of these ions was discernible.

Chloride and Sulfate: Chloride varied from a high of 60 ppm on 21 May 1970 to a low of 5 ppm during high water levels in 1972. The amounts usually encountered ranged 11-29 ppm. The greatest quantity was present when dead fish were decomposing in the pond and lesser quantities were present during periods of high water. The amounts occurring in this pond are typical of those usually found in inland fresh waters in south Florida.

Sulfate usually ranged 0.0-8 ppm. During the fish kill it rose to 14, 19, and 34 ppm on 19, 21 and 24 May 1970, respectively. This was a result of the decay of dead fish. By 27 May the sulfate concentration dropped to 6 ppm and declined further during June and July of that year.

Phosphate, Nitrate and Nitrite: During the fish kill, total phosphate was present in unusually large quantities, reaching a high of 36 ppm on 21 May 1970. During this time it was always higher than 10 ppm due to the decay of fish and the breakdown of the plankton bloom that followed. The quantities present preceeding and during the 2 mo following the fish kill, ranging 0.15-0.90 ppm, are more representative of usual conditions in the pond.

Dissolved inorganic phosphate was also present in large quantities during the fish kill, reaching a high of 13 ppm on 19 May 1970. The amounts present before and in the June-August period following the fish kill, ranged from 0.10-0.99 ppm.

Between 3 June and 20 August 1970, 11 measurements of nitrate were made; the amounts ranged 0.005-0.10 ppm with an average of 0.046. These very small amounts are in sharp contrast to conditions during the fish kill when nitrate was elevated to almost 2 ppm by the decomposition of organic matter.

Nitrite also reached a high value (0.12 ppm) at the end of the fish kill. During that event both nitrate and nitrite peaked on 17 May, subsided, then peaked again on 27 May. On the first of these dates the decay of fish was at a maximum and on the second date the intense plankton bloom was deteriorating. Before and after the fish kill the amounts varied 0.005-0.02 ppm.

Other Chemicals: Silica, measured periodically from 1969-1972, showed considerable fluctuation; the highest value (4.2 ppm) occurred on 27 June 1970. Amounts ranging 1.3-2.6 ppm during the fish kill may have been caused in part by release of silcate from the sediment by reducing conditions. Quantities before and after the fish kill ranged 0.08-3.2 ppm.

The 17 measurements of manganese, taken in 1969 and 1970, ranged 0.0-1.1 ppm, with the highest value obtained in May 1970. Decomposition of fish and plankton and resultant anaerobic conditions may have caused release of manganese from the sediment.

Iron was present in measurable amounts only on a few dates. On 22 April 1969 the amount was 0.22 ppm and on 16 July 1969, 0.05 ppm. During the fish kill, the presence of iron on 19 May (0.01 ppm) and 21 May 1970 (0.18 ppm) may have been the result of release of ferrous ions into the water from the sediment because of oxygen depletion.

Other inorganic and organic substances were measured only a few times, and the results in Table 1 are representative.

Specific Conductance: Specific conductance fluctuated seasonally, being highest during low water conditions and lowest during periods of high water. In late summer and fall measurements usually ranged 184-290 μmho/cm^2 at 25 C. During the low water period of late winter and spring, conductivity ranged from 300-540. On 13 occasions, measurements were taken at the surface and at the bottom; in all cases the amounts were similar. Although fluctuations as great as 90 units occurred from one sampling interval to the next, there were periods when little change occurred. In 1972, from late February to May, conductance remained virtually constant, ranging 396-440. During the fish kill, conductivity was 495 at the beginning, 615 at the end, and reached a peak of 998 on 21 May 1970. After June it dropped markedly and ranged 184-337 during June, July and August 1970.

Turbidity and Color: The pond was relatively clear for most of the summer. Turbidity, during ordinary conditions, ranged from 5 JTU in high water to 15 JTU during low water. During the fish kill and plankton bloom, the turbidity increased drastically to a high of 165 JTU. Following the fish kill and subsidence of the plankton bloom, the turbidity fell to usual levels.

Color usually ranged from 10 color units during high water to 40 units during low water. The hue of the water under usual conditions was slightly brown. During the fish kill and plankton bloom, total color increased to levels of 85-380 units, a condition which lasted until 2 wk after the fish kill when the color measured only 20 units. During the fish kill, centrifuged water still had color ranging 30-210 units. Under such conditions the hue of the pond water was bright green.

Organic Matter: Amounts of dissolved organic matter in the pond were usually very high even compared to the elevated characteristic of most south Florida waters (Gonyea and Hunt, 1970). At the height of decomposition during the fish kill, 147 ppm of organic matter was measured. The smallest quantity, (12.3 ppm), was measured on 27 June 1970 about 1 mo after the fish kill. From 5 June to 16 December 1970 the quantities of organic matter in 12 samples ranged 12.3-61.5 with an average of 32.6 ppm. During 1971-1973, 27 measurements ranged 23.9-56.8 ppm with a mean of 36.5. During this interval the variation from one sampling period to the next was usually less than 10 ppm but was sometimes as great as 18 ppm. The amounts were generally greater during January to March than at other times of the year.

Pesticides: Samples of water, sediment and fish were collected in April and July, 1969 and analyzed for chlorinated hydrocarbon insecticides (Table 4). The concentrations found in sediments obtained in April were higher than those found in samples collected that month in other parts of the Everglades and Big

TABLE 4. Chlorinated hydrocarbon insecticides in water, sediment, and fish from alligator pond.

	DDD	DDE	DDT	Dieldren
April 1969				
Water (μg/1)	0.00	0.00	0.01	0.00
Sediment (μg/kg)	3.69	4.74	7.96	0.00
July 1969				
Water (μg/1)	0.00	0.00	0.00	0.00
Sediment (μg/kg)	0.00	0.00	8.30	0.00
Fish (μg/kg)				
Lepisosteus platyrhincus	21.45	35.68	101.10	3.27
Lepomis microlophus	0.00	46.77	6.00	0.00
Ictalurus natalis	0.00	22.04	0.00	0.00
Poecilia latipinna	0.00	18.94	0.00	0.00

Cypress Swamp by McPherson (1969). In general, however, the levels of these compounds fell within the usual range found in southern Florida (A. Higer, pers. comm.).

The pond was remote from the nearest road, habitations, or areas where pesticides were being used. Contamination presumably was the result of transport of these substances by wind and rainfall. Movement of surface waters and of fish and other animals into the pond from distant areas where pesticides were present may also have had an effect.

The amounts of pesticides in the sediment indicate that some accumulation has taken place. The rather high levels of 4 compounds found in spotted gar (*Lepisosteus platyrhincus*) and the incidence of DDE in 3 other fish species suggested that these substances were cycled through food chains resulting in accumulations in carnivorous fish. There is a distinct possibility that alligator ponds may serve as ecosystem sinks for pesticides as well as other persistent exotic substances.

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FISHES OF THE LITTORAL ZONE, PINELLAS COUNTY, FLORIDA[1]

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ABSTRACT: *Fishes along the beaches of Pinellas County, Florida, were sampled by beach seine during 1970 and 1971. A total of 228,667 individuals representing 30 families and 62 species was collected. Individuals were most abundant in April and September and least abundant in January and February. Several species were more numerous in July through September than in the remaining months. Species diversities fluctuated throughout the year. Ten species* (Harengula jaguana, Anchoa hepsetus, A. mitchilli, Menidia beryllina, Menticirrhus littoralis, Opisthonema oglinum, Menticirrhus focaliger, Trachinotus carolinus, T. falcatus, *and* A. cubana) *comprised 97.7% of the total number of individuals. The fishes were relatively small; most individuals were less than 100 mm total length.*[*]

THE littoral zone of the Gulf of Mexico off Pinellas County, Florida, was studied to provide background data on the fauna and habitat before beach restoration (Saloman, 1974). This report on the fishes is part of that study.

Previous studies of fishes inhabiting waters along the beach of Pinellas County include those of Springer and Woodburn (1960) and Finucane (1969), who each sampled one station on Long Key with a beach seine, and that of Fable and Saloman (1974), who surveyed the recreational fishery on 3 piers on Sand Key, Florida. Studies of fishes of the sandy beaches of the Gulf of Mexico in general are uncommon. Gunter (1945 and 1958), Reid (1956), and MacFarland (1963) reported on shore fishes in Texas; Gunter and Hall (1965) at Sanibel Island, Florida; Holland, Chambers, and Blackman (1973) at Lido Key, Florida; and Naughton and Saloman (1978) at Panama City, Florida.

STUDY AREA—The study area includes the gulf beaches of 3 barrier islands (Long Key, Treasure Island, and Sand Key) on the central west coast of Florida (Fig. 1). Three passes separate the islands and connect the Gulf of Mexico to either Boca Ciega Bay or to the intracoastal waterway. The 3 islands are long and narrow, ranging from 25.7 km (Sand Key) to 6.5 km (Treasure Island) in length. Elevations do not exceed 3 m (U.S. Secretary of the Army, 1966). The bayward side of the 3 islands is almost entirely lined with seawalls and has numerous fingers of filled land for residential use. The gulf side of Sand Key has numerous groins and fishing piers. The northern end of Treasure Island also has several groins plus an emergent sandbar created by a spoil from maintenance dredging of Johns Pass. No groins are found on Long Key, but a small jetty is located at Blind Pass.

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The water depth along most of the coastline increases to at least 1.8 m and decreases over a sandbar to about 0.9 m within 30.5 m offshore. At the northern end of Sand Key, the slope of the bottom is more gradual than the southern portion of the study area. Submerged rooted vegetation is absent. A more detailed description of the beach and offshore area is given by Saloman (1974).

The surface sediments of the nearshore zone along the beach consisted mainly of white sand, shells, and shell fragments (Saloman, 1974). The average mean grain size was 0.9 phi. The shells and shell fragments caused the mean grain size to be fairly large, as the percentage of carbonate averaged 43.6% and ranged from 12-69%. The average weight percent of sand was 78.4 and organic matter 17.3.

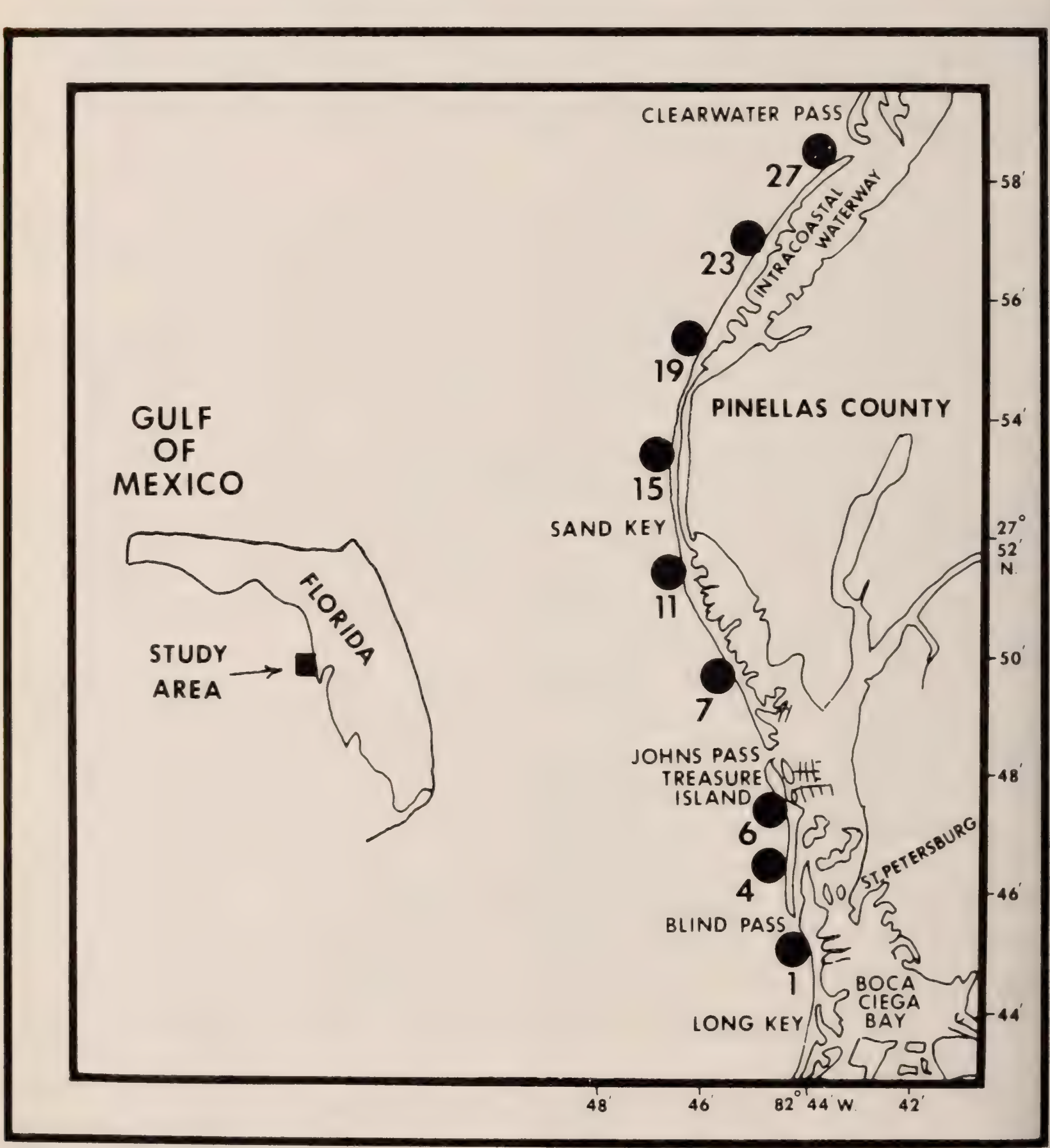

Fig. 1. Locations of beach seine stations.

Nine stations were located at 0.93 km apart, from the northern end of Long Key to the northern end of Sand Key (Fig. 1).

MATERIALS AND METHODS—Fishes were collected monthly from December 1970 through November 1971 with a 30.5 × 1.8 m beach seine made of 0.64 cm bar-mesh nylon netting. At each station, the seine was set perpendicular to the shore and pulled in an arc toward shore. Two sets were made at each station, with the net pulled in opposite directions in the 2 sets.

Specimens were preserved in a 10% Formalin-seawater solution and later identified to species and enumerated. Total length, to the nearest mm, was recorded on all individuals of each species, when sample size was less than 50, or a random subsample of 50 individuals of each species, when sample size was greater than 50.

A water sample for salinity and turbidity was taken at each station. Salinity was measured in the laboratory with a Goldberg refractometer; turbidity was measured with a Hach turbidimeter. Water temperature was measured in the field with a mercury thermometer.

The Shannon Index of general diversity ($\bar{H}$) where $\bar{H} = -\Sigma \frac{(n_i)}{N} \log_e \frac{(n_i)}{N}$ with n_i as the number of individuals of a given species and N as the total number of individuals was calculated for each station and each month (Odum, 1971).

HYDROLOGY—Water temperature, salinity, and turbidity varied seasonally; temperature and salinity exhibited a narrow range of variability during any particular month. Water temperatures averaged 23.0°C and ranged from 14.7-30.0°C. Salinities averaged 34.0‰ and ranged from 30.9-35.7‰. Turbidities averaged 10.9 JTU (Jackson Turbidity Unit) and ranged from 2.8-31.0 JTU (Table 1).

SEASONALITY OF CATCH—A total of 228,667 individuals representing 62 species and 30 families was caught during the sampling period of December 1970 through November 1971 (Tables 2 and 3). A single large catch of 40,776 *Anchoa hepsetus* at Station 15 in April 1971, accounted for 17.8% of the total catch for the entire survey. This catch tended to bias the data in regards to season, station, and species abundance.

The number of individuals varied by season. The winter months (December-February) accounted for 2.5% of the catch; spring (March–May) 25.0%; summer (June-August) 23.6%; fall (September-November) 48.9% (Table 2). If the single catch of *A. hepsetus* at Station 15 in April were deleted from the catch during spring, the percentage of catch for spring would decrease from 25.0-8.8%. The number of species was highest during July-September and lowest in December (Table 2).

The general index of species diversity ($\bar{H}$) varied monthly. The lowest monthly diversity was in March and the highest was in July (Table 2).

CATCH BY STATION—The number of individuals per station for the 12-mo sampling period varied from a low of 10,990 at Station 11 to a high of 65,799 at Station 15 (Fig. 2). If the large catch of *A. hepsetus* at Station 15 in April 1971

Table 1. Hydrological data from beach-seine stations on the gulf shores of Pinellas County, Florida, 1970-71.

	Dec. 1970	Jan. 1971	Feb. 1971	Mar. 1971	Apr. 1971	May 1971	June 1971	July 1971	Aug. 1971	Sept. 1971	Oct. 1971	Nov. 1971	Yearly mean, range, & no. of observations
Water temperature (°C)													
Mean	17.1	19.0	15.7	16.5	21.1	26.0	28.3	29.3	29.4	28.4	25.3	20.4	23.0
Range	16.9-17.3	18.9-19.1	14.7-16.6	15.2-18.0	19.9-21.9	25.3-26.7	27.3-29.4	28.9-30.0	28.9-29.8	27.5-29.3	24.0-26.7	18.2-22.0	14.7-30.0
No. of observations	9	9	9	9	9	9	9	9	9	9	9	9	108
Salinity (‰)													
Mean	34.94	34.59	33.73	32.77	34.63	34.76	35.52	35.22	34.41	32.02	33.07	32.38	34.00
Range	34.22-35.39	34.28-34.83	33.28-34.22	32.11-33.56	34.22-35.56	34.39-35.39	35.33-35.72	34.72-35.67	34.17-35.00	31.39-32.94	32.00-33.33	30.94-33.33	30.94-35.72
No. of observations	9	9	9	9	9	9	9	9	9	9	9	9	108
Turbidity (JTU)													
Mean	7.6	9.0	16.8	17.2	14.7	6.2	7.3	6.7	9.1	11.6	14.3	10.8	10.9
Range	5.3-10.2	4.6-15.7	7.2-23.7	13.8-20.0	6.2-31.0	2.9-10.1	2.8-13.8	4.3-9.6	3.0-16.2	4.4-31.0	7.2-28.7	5.5-14.7	2.8-31.0
No. of observations	9	9	9	9	9	9	9	9	9	9	9	9	108

TABLE 2. Most abundant fishes caught with a beach seine at stations on the gulf shores of Pinellas County, Florida, December 1970–November 1971.

	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Total Number	Total %
Harengula jaguana	304	165	12	40	1,382	274	2,113	27,296	12,039	47,081	8,161	17,064	115,931	50.7
Anchoa hepsetus	10	4	29	59	41,736	1	208	92	9	7,727	3	28	49,897	21.8
Anchoa mitchilli	2,382	201	1,366	6,164	4,756	0	0	0	130	1,768	38	4	16,809	7.3
Menidia beryllina	39	4	5	17	85	1,898	382	145	108	8,624	826	176	12,309	5.4
Menticirrhus littoralis	321	176	33	50	4	13	411	1,593	2,209	4,999	999	521	11,329	4.9
Opisthonema oglinum	0	0	0	0	0	3	25	13	63	43	27	10,129	10,303	4.5
Menticirrhus focaliger	0	3	1	11	25	189	1,386	1,248	0	108	21	28	3,020	1.3
Trachinotus carolinus	4	0	1	3	0	6	584	283	56	266	216	74	1,493	0.6
Trachinotus falcatus	23	16	2	3	12	14	2	0	119	877	194	107	1,369	0.6
Anchoa cubana	255	95	0	3	3	0	0	0	991	0	0	0	1,347	0.6
Oligoplites saurus	6	1	0	0	1	8	16	8	132	755	148	214	1,289	0.5
Menticirrhus americanus	0	0	0	0	0	0	517	363	0	0	0	0	880	0.4
Strongylura marina	11	5	0	10	44	14	267	184	71	66	3	1	676	0.3
Mygil trichodon	0	0	2	99	8	11	31	138	98	47	45	18	507	0.2
Eucinostomus gula	7	1	0	0	0	0	0	0	339	113	0	6	466	0.2
Hyporhamphus unifasciatus	1	0	0	0	2	162	39	0	0	0	0	2	206	0.1
Chloroscombrus cyrysurus	0	0	0	0	0	0	2	3	5	182	3	0	195	0.1
Caranx chrysos	0	0	0	0	1	0	0	7	119	0	0	0	127	0.1
No. of Species[1]	15	25	18	20	21	19	25	28	27	28	23	22		
Total individuals[1]	3,388	725	1,507	6,498	48,110	2,623	6,015	31,423	16,513	72,733	10,719	28,413	228,667	100.0
$(\overline{H})$ for each month[1]	1.080	1.869	0.500	0.315	0.490	1.490	0.614	1,897	1.043	1.227	0.938	0.886		

[1] Computations include those species listed in Table 3.

TABLE 3. Fishes comprising less than 0.1% of the catch caught by beach seine on the gulf shores of Pinellas County, Florida, 1970-71.

Species	No.	Species	No.
Lagodon rhomboides	66	*Pomatomus saltatrix*	5
Sardinella anchovia	55	*Brevoortia patronus x smithi*	4
Elops saurus	52	*Paralichthys* sp.	4
Caranx Hippos	40	*Fundulus similis*	4
Leiostomus xanthurus	28	*Sphyraena guachancho*	4
Brevoortia smithi	26	*Lagocephalus laevigatus*	3
Pogonias cromis	25	*Chilomycterus schoepfi*	3
Scomberomorus maculatus	21	*Centropomus undecimalis*	3
Archosargus probatocephalus	20	*Cynoscion nebulosus*	3
Eucinostomus argenteus	17	*Chaetodipterus faber*	2
Arius felis	17	*Etropus crossotus*	1
Sphyraena borealis	13	*Urophycis floridanus*	1
Paralichthys albigutta	12	*Monacanthus hispidus*	1
Cynoscion arenarius	12	*Orthopristis chrysoptera*	1
Astroscopus y-graecum	10	*Decapterus* sp.	1
Trachinotus goodei	10	*Rhinoptera bonasus*	1
Gymnura micrura	9	*Aluterus schoepfi*	1
Synodus foetens	8	*Brevoortia patronus*	1
Bairdiella chrysura	7	*Floridichthys carpio*	1
Sphoeroides nephelus	7	*Fundulus*	1
Prionotus tribulus	6	*Bagre marinus*	1
Dasyatis sayi	6	*Prinonotus scitulus*	1

were deleted, Station 6 with 41,982 would rank first in total numbers of individuals, followed by Station 15.

The number of species varied from 28 at Station 27 to 37 at Station 6. Numbers of species were higher at the southern end of the study area (Stations 1, 4, and 6) than at the northern end (Stations 19, 23, and 27).

The general index of species diversity ($\bar{H}$) varied from station to station. The lowest diversity was at Station 15 (1.324) and the highest at Station 7 (2.987). Stations 1, 4, 6, 11, 19, 23, and 27 had values of 2.137, 2.503, 2.342, 2.921, 2.467, 2.310, and 1.928, respectively.

MOST ABUNDANT SPECIES—Ten species (*Harengula jaguana, Anchoa hepsetus, A. mitchilli, Menidia beryllina, Menticirrhus littoralis, Opisthonema oglinum, Menticirrhus focaliger, Trachinotus carolinus, T. falcatus,* and *A. cubana*) comprised 97.7% of the total number of individuals (Table 2). Three species, *H. jaguana, M. beryllina,* and *M. littoralis,* were present during all months; *H. jaguana* and *M. littoralis* were present at a majority of the stations during 11 of 12 mo. The remaining species were either absent during some months or their distributions were not as uniform along the beach as those of *H. jaguana* and *M. littoralis* (Table 4).

The seasonal mean and range of total lengths (mm) for the 10 dominant species are in Table 4. Most individuals of the 10 dominant species had mean lengths between 50 and 100 mm. The largest mean length (169 mm) occurred in the spring for *T. falcatus*; the smallest mean length (28 mm) occurred in the summer for *T. falcatus* (Table 5).

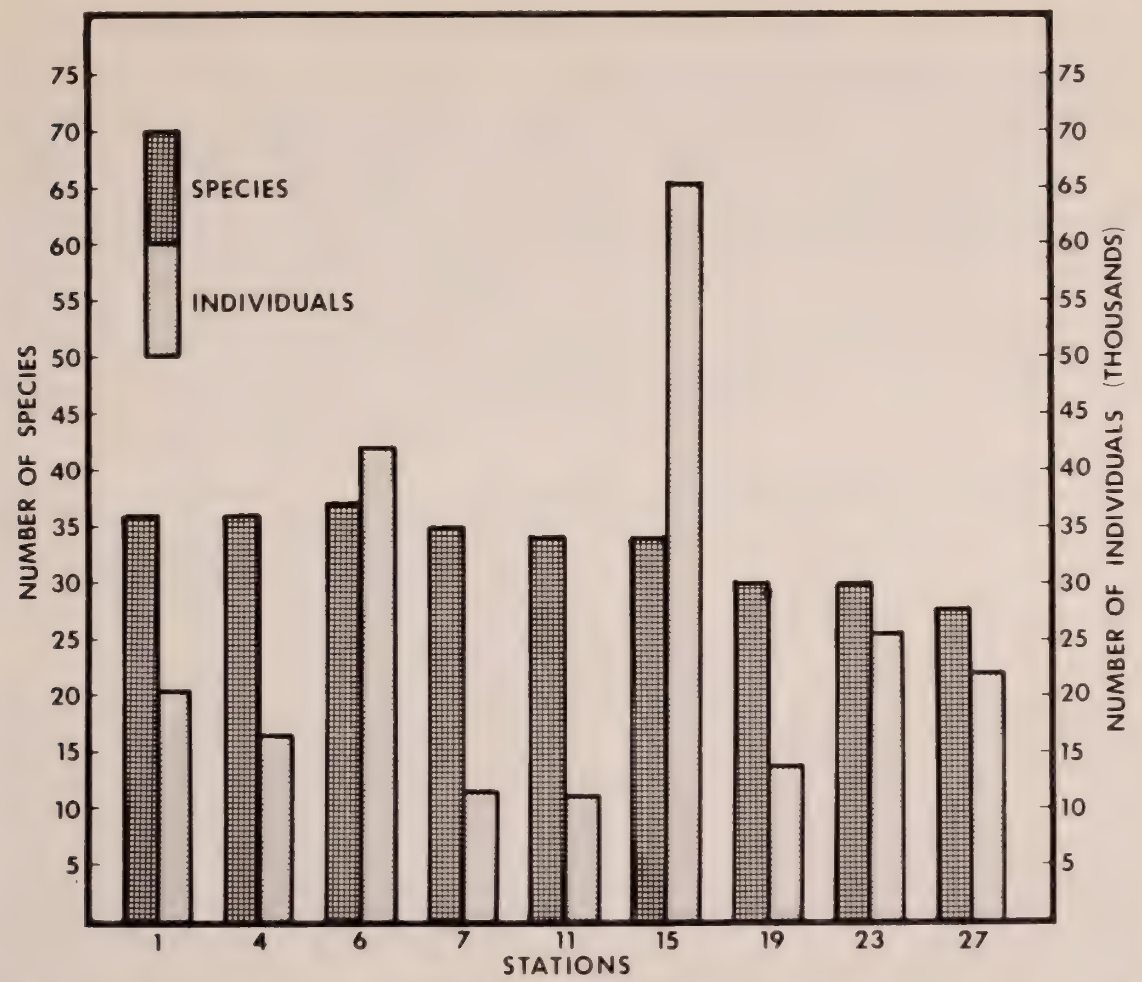

Fig. 2. Number of species and individuals of fish collected at beach seine stations on gulf shores of Pinellas County, Florida, December 1970-November 1971.

Discussion—The composition of the dominant fishes within the fauna inhabiting the various beaches around the periphery of the Gulf of Mexico vary by locality. Some species, *H. jaguana, M. littoralis, M. beryllina,* and *A. mitchilli,* appear dominant in most of the reports of gulf beaches (Gunter 1945 and 1958; Springer and Woodburn, 1960; Gunter and Hall, 1965; MacFarland, 1963; Holland, Chambers, and Blackman, 1973; and Naughton and Saloman (1978). The difference in abundance and composition is probably due to several factors, such as the type of gear and method of collection. Also, each beach has its own characteristic slope, substrate composition, wave energy, currents, erosion or accretion of substrate, and water quality. Differences in abundance and composition exist even in areas located in close proximity to each other. On Long Key, Springer and Woodburn (1960) reported that 6 species were abundant at their single station sampled monthly for 14 consecutive mo, but only 3 of their species (i.e., *H. jaguana, M. littoralis,* and *T. falcatus)* were in the dominant 10 in our study. In a study of the fish fauna of Panama City Beach, Florida, Naughton and Saloman (unpublished MS) found that 4 of the 10 most abundant species (i.e., *H. jaguana, M. beryllina, M. littoralis,* and *T. carolinus)* were the same as the dominant species inhabiting waters along the beaches of Pinellas County using the same gear and methods.

The size of the fish caught along the beaches tends to be small, due to the

TABLE 4. The number of stations at which the 10 most abundant species occurred.

Species	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.
Harengula jaguana	6	5	5	7	7	2	8	9	9	8	9	9
Anchoa hepsetus	3	3	3	7	9	1	1	1	0	5	1	2
Anchoa mitchilli	6	8	7	7	9	0	0	0	4	1	2	1
Menidia beryllina	1	1	2	1	5	6	1	3	1	8	2	3
Menticirrhus littoralis	8	9	9	7	3	5	9	9	9	9	8	8
Opisthonema oglinum	0	0	0	0	0	2	4	5	2	6	6	9
Menticirrhus focaliger	0	2	1	4	6	9	9	8	0	5	4	2
Trachinotus carolinus	2	0	1	1	0	2	9	9	8	9	8	9
Trachinotus falcatus	4	1	1	1	1	1	1	0	8	8	8	8
Anchoa cubana	3	3	0	2	1	0	0	0	3	0	0	0

TABLE 5. Sizes (mm) of the 10 most abundant fishes caught by beach seine on gulf shores of Pinellas County, Florida, December 1970–November 1971.

	Winter (Dec.-Feb.)		Spring (Mar.-May)		Summer (June-Aug.)		Fall (Sept.-Nov.)	
Species	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Harengula jaguana	74	43-132	87	58-188	73	17-166	62	30-100
Anchoa hepsetus	101	79-116	56	12-140	79	14-117	38	30- 88
Anchoa mitchilli	51	27- 70	54	37- 70	35	18- 56	40	27- 80
Menidia beryllina	79	48- 97	87	58-172	100	58-161	80	45-125
Menticirrhus littoralis	72	24-193	109	22-179	53	17-197	89	19-220
Opisthonema oglinum	0	0[1]	94	80-119	94	52-180	65	37-105
Menticirrhus focaliger	67	47- 93	56	21-114	67	18-164	56	20-115
Trachinotus carolinua	95	59-135	82	42-166	43	12-250	73	12-185
Trachinotus falcatus	121	49-204	169	110-196	28	12- 62	83	15-183
Anchoa cubana	44	34- 62	51	33- 71	52	28- 57	0	0[1]

[1] Not present.

mesh size of the gear and net avoidance by larger fishes. Most individuals were below 100 mm total length. Similar findings were also noted for the most abundant species inhabiting the waters along other beaches (Gunter 1945 and 1958; Reid 1956; Springer and Woodburn, 1960; Gunter and Hall, 1965; and Naughton and Saloman (1978).

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Biological Sciences

REPRODUCTIVE PARAMETERS FOR NINE AVIAN SPECIES AT MOORE CREEK, MERRITT ISLAND NATIONAL WILDLIFE REFUGE, FLORIDA

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ABSTRACT: *Nine avian species were studied during the 1974-1975 breeding season at Moore Creek Rookery, Merritt Island National Wildlife Refuge, Brevard County, Florida. Nesting dates, nest location, internest distance, clutch size, and mortality of eggs and young for double-crested cormorant, anhinga, great blue heron, great egret, snowy egret, Louisiana heron, wood stork, glossy ibis, and white ibis are discussed.*°

IN RECENT YEARS there has been an increased interest in the biology of colonial birds. Evidently members of the heron family (Ardeidae) are good indicator species of disturbances to wetland habitats. During the 1974-1975 breeding season, reproductive parameters for 9 avian species were studied at Moore Creek Rookery, Merritt Island National Wildlife Refuge, Brevard County, Florida. The species were: double-crested cormorant (*Phalacrocorax auritus*), anhinga (*Anhinga anhinga*), great blue heron (*Ardea herodias*), great egret (*Casmerodius albus*), snowy egret (*Egretta thula*), Louisiana heron (*Hydranassa tricolor*), wood stork (*Mycteria americana*), glossy ibis (*Plegadis falcinellus*), and white ibis (*Eudocimus albus*). No study has been conducted on this rookery other than a few censuses made by Refuge personnel.

STUDY AREA—Moore Creek Rookery is within the Kennedy Space Center in an area administered by Merritt Island National Wildlife Refuge. It is not disturbed by human intrusion because of NASA's restrictions. The rookery is located on 2 islands near the mouth of Moore Creek impoundment (28° 31′, 80°42′W) and about 5 km west of the Vertical Assembly Building (VAB). The island designated in this paper as Island 1 was about 1.0 ha; Island 2 was about 4.2 ha. The islands were about 100 m apart. The dominant vegetation on both islands was white mangrove (*Laguncularia racemosa*) which ranged in height from 1.5-6.5m.

Fourteen species nested in the rookery. Estimated numbers of nesting pairs were: 200 cormorants, 50 anhingas, 20 great blue herons, 150 great egrets, 500 snowy egrets, 750 cattle egrets (*Bubulcus ibis*), 400 Louisiana herons, 30 little blue herons (*Florida caerula*), 5 green herons (*Butorides virescens*), 20 black-crowned night herons (*Nycticorax nycticorax*), 100 wood storks, 60 glossy ibises, 1000 white ibises, and 10 boat-tailed grackles (*Cassidix mexicanus*).

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METHODS—The rookery was visited twice a week from 17 December 1974 to 29 May 1975. About 500 nests of the 9 species were tagged and observations were completed on 440. Double-crested cormorant, anhinga, and about one-half of the wood stork nests were observed with a mirror attached at the end of a long pole. Eggs in these nests were not marked. For all other species, an indelible, felt-tip pen was used to mark the eggs. Nest heights were measured from the island substrate to the upper nest rim. Internest distance was measured with a tape from the nest rim to the rim of the nearest nest. Student's t-test was used to determine the significance between means; the significance level was 0.05, unless otherwise noted.

NESTING DATES—Great blue herons were the first to nest. On 17 December 1974, a nest with 4 eggs was found. All other great blue heron nests were built in January and through the second week of February.

Double-crested cormorants built nests on the north and northwest side of Island 2 during the latter part of December. Peak nest-building was attained by the second week of January. Cormorants then built nests on Island 1 and at various locations on Island 2, but in smaller numbers. They were still building or renesting in old nests when observations terminated on 29 May.

Wood storks were first observed carrying nesting material on 1 February. The first eggs of this species were found on 1 March. On 4 February the first nesting activity by anhingas was observed. Great egrets and a few snowy egrets had territories on Island 1 by 4 February. Nests with eggs of both species were found on 8 February. On 15 February, a few Louisiana heron nests with eggs were found. The first white ibis nest with 1 egg was found on 1 March and the first glossy ibis nest, which had 2 eggs, was found on 29 March.

Nesting dates were similar to those published except for the snowy egret, Louisiana heron, and white ibis which nested earlier than expected. The earliest reported nesting date for snowy egrets in Florida was 18 February at Greynold's Park, North Miami Beach (Palmer, 1962). We found a nest with 1 egg on 8 February. Palmer reported that Louisiana herons in Florida began to lay in mid-March; at Moore Creek eggs were found on 15 February. The first white ibis egg was found on 1 March, whereas Palmer reported nesting dates from late March (southern region of Florida) to April and May (central and northern regions). Unusually high daily temperatures during the latter part of January 1975 may have caused these birds to nest early.

NEST HEIGHT AND LOCATION—Nest heights for all species are in Table 1. Comorant nests were built significantly higher than those of all other species. Comparison of cormorant mean nest height with mean nest height for all other species gave t values greater than or equal to 5.07 ($p < 0.005$). Most cormorants nested on Island 2.

Great blue herons and great egrets nested primarily on Island 1, while snowy egrets and glossy ibises nested primarily on Island 2. Anhingas nested in the peripheral and interior areas of both islands. Great blue heron nests were scattered throughout Island 1, but 4 tagged nests on Island 2 were on the western side. Great egrets, snowy egrets, and glossy ibises nested in the interior areas.

TABLE 1. Nest heights for 9 avian species at Moore Creek, 1975.

Species	N	Range (m)	Mean ± S. D.
Double-crested Cormorant	83	2.8-6.1	4.72 ± 0.52
Anhinga	15	2.5-5.1	3.91 ± 0.80
Great Blue Heron	16	2.5-5.2	3.69 ± 0.82
Great Egret	59	1.2-2.4	1.68 ± 0.26
Snowy Egret	60	0.9-2.4	1.67 ± 0.33
Louisiana Heron	73	1.3-2.2	1.69 ± 0.23
Wood Stork	24	1.7-4.6	2.78 ± 0.87
Glossy Ibis	23	0.5-2.1	1.50 ± 0.44
White Ibis	87	1.0-2.7	1.78 ± 0.35

Although great and snowy egrets nested at about the same height, they had different nest sites; great egrets built in exposed areas, while snowy egrets built in protected areas among mangrove branches. Glossy ibis nests were placed significantly lower than all other species ($t = 2.02$, $p < 0.025$). This was the only species that nested at the base of mangroves on both islands.

Wood storks nested only on Island 1. Louisiana herons and white ibises nested only on Island 2. The herons were more concentrated at the southern end of the island than in the interior where snowy egrets predominated.

Nest stratification at Moore Creek partially resembled the results reported by other investigators. In southern Ghana, the long-tailed shag (*Phalacrocorax africanus*) nested in the middle and upper branches, whereas the African darter (*Anhinga rufa*) nested around the peripheral areas (Bowen et al., 1962). At Moore Creek, cormorants nested only around the peripheral areas, whereas anhingas nested both at the periphery and in the interior areas. In Arkansas, Meanley (1955) found that great egrets nested in the interior areas as they did at Moore Creek. Great egrets nested higher than did snowy egrets in Arkansas (Meanley, 1955), on Little Marin Island in San Francisco Bay (Ralph and Ralph, 1958), and on Riomar Island near Vero Beach, Florida (Maxwell and Kale, 1977). At Moore Creek, these species nested almost at the same height. Meanley (1955) found snowy egrets nesting in the peripheral areas; at Moore Creek they occupied the interior areas. Jenni (1969) reported that snowy egrets and Louisiana herons nested at the same height at the inland Lake Alice, Florida herony, as they did at Moore Creek.

INTERNEST DISTANCE—Distance to nearest neighboring nest was measured for 314 nests (Table 2). Wood storks nested closer to all nearest neighbors than did any other species. Only white ibises lacked a mean internest distance significantly greater than that of wood storks ($t = 1.57$, $p < 0.10$). Great egrets maintained the greatest internest distance. Glossy ibises and Louisiana herons had nearly the same internest distance ($t = 0.41$, $p < 0.25$). Snowy egrets nested significantly closer to all neighbors than did Louisiana herons ($t = 2.25$, $p < 0.025$).

Table 3 gives mean internest distance for conspecific or other neighbors.

TABLE 2. Distance to nearest neighbor for 6 species at Moore Creek, 1975.

Species	Nests	Range (m)	Mean ± S. D.
Great Egret	50	0.4-4.7	1.58 ± 0.92
Snowy Egret	65	0.4-5.3	0.91 ± 0.62
Louisiana Heron	74	0.4-2.6	1.13 ± 0.54
Wood Stork	20	0.3-0.9	0.48 ± 0.17
Glossy Ibis	21	0.3-2.0	1.06 ± 0.47
White Ibis	84	0.2-2.4	0.64 ± 0.45

Great egrets had a significantly greater mean internest distance when a conspecific was nearest neighbor than when another species was nearest neighbor ($t = 1.86$, $p < 0.05$). This was not true for both snowy egret and Louisiana heron. Glossy ibis were widely dispersed through the rookery; only 1 of 21 nests had another glossy ibis as nearest neighbor. For 17 of 20 wood stork nests, another wood stork was the nearest nester. White ibis mean internest distance was significantly less when another white ibis was nearest neighbor than when the nearest neighbor was another species ($t = 4.22$, p. < 0.005).

Internest distances within rookeries have received little attention. In studies on black-headed gulls (*Larus ridibundus*) and Brewer's blackbirds (*Euphagus cyanocephalus*), Kruuk (1964) and Horn (1968), respectively, discussed internest distance in relation to predation within colonies. Kruuk observed that if predators are attacked by owners of a nest at a distance greater than the average internest distance, then there will be more potential defenders within a colony than at the edge. At Moore Creek no evidence of mammalian predation was found. However, avian predation was greatest for wood storks and white ibises. Clumping of wood storks and white ibises nests might be a defense mechanism against avian predators. Bent (1926) reported that fish crows (*Corvus ossifragus*) observed at Bird Key, Florida, stole more eggs from white ibises than from herons because the soft bill of the ibis was not a formidable weapon as was the sharp, stout heron's bill. Burger and Miller (1977) studied internest differences

TABLE 3. Conspecific and interspecific comparison of internest distance for 4 species at Moore Creek, 1975.

Species	Neighbor	N	Range (m)	Mean ± S. D.
Great Egret	same	32	0.7-3.5	1.78 ± 0.72
	other	18	0.4-4.7	1.29 ± 1.16
Snowy Egret	same	22	0.4-1.4	0.78 ± 0.36
	other	43	0.4-5.3	0.97 ± 0.75
Louisiana Heron	same	15	0.5-2.6	1.04 ± 0.65
	other	59	0.4-2.4	1.14 ± 0.51
White Ibis	same	65	0.2-2.4	0.54 ± 0.39
	other	19	0.4-2.0	0.99 ± 0.47

TABLE 4. Clutch size of 9 species for nesting attempts hatching young at Moore Creek, 1975.

Species	N	Clutch Size	Mean ± S. D.
Double-crested Cormorant	74	2-4	3.2 ± 0.62
Anhinga	11	3-5	4.1 ± 0.54
Great Blue Heron	12	2-4	3.0 ± 0.17
Great Egret	45	1-4	2.4 ± 0.62
Snowy Egret	60	2-4	3.0 ± 0.56
Louisiana Heron	64	2-4	3.0 ± 0.50
Wood Stork	16	2-4	2.9 ± 0.44
Glossy Ibis	9	1-3	2.4 ± 0.73
White Ibis	77	1-3	2.4 ± 0.57

TABLE 5. Comparison of early and late clutches of 3 species at Moore Creek, 1975.

Species/Hatching Dates	N	Clutch Size	Mean ± S. D.
Great Egret			
8 Mar-22 Mar	22	1-4	2.8 ± 0.61
25 Mar-22 Apr	23	1-3	2.2 ± 0.51
Snowy Egret			
8 Mar-8 Apr	49	2-4	3.1 ± 0.52
22 Apr-6 May	11	2-4	2.7 ± 0.65
Louisiana Heron			
11 Mar-5 Apr	49	2-4	3.1 ± 0.44
15 Apr-10 May	15	2-3	2.6 ± 0.51

TABLE 6. Nesting attempts and eggs laid for 9 species at Moore Creek, 1975.

Species	Nests	Nesting Attempts	Eggs Laid
Double-crested Cormorant	83	90	285
Anhinga	15	21	69
Great Blue Heron	16	16	46
Great Egret	59	67	152
Snowy Egret	66	67	201
Louisiana Heron	73	80	236
Wood Stork	24	24	88
Glossy Ibis	23	24	54
White Ibis	87	104	251

in white-faced ibises (*Plegadis chihi*) and glossy ibises. They found that glossy ibises appeared to nest randomly with respect to the species nearest neighbor.

Clutch Size—Table 4 gives the clutch size for all nesting attempts that hatched young. In most instances, clutch size agreed with published reports. However, mean clutch size for the Moore Creek herons is more similar to that of the Riomar Island herons near Vero Beach, Florida (Maxwell and Kale, 1977) than to the inland Lake Alice, Florida herons at Gainesville (Jenni, 1969).

Great egrets, snowy egrets, and Louisiana herons had 2 egg-laying periods (Table 5). There was a decrease in mean clutch size for the 3 species and the means are significantly different. Jenni (1969) also reported a decrease in snowy egret clutch size late in the nesting season at Lake Alice.

Clutch size was compared to brood success for cormorants, great egrets, snowy egrets, Louisiana herons, and white ibises. Cormorant clutches of 2 resulted in the smallest brood size at 6 wk; however, clutches of 3 and 4 produced nearly equal broods. Great egret clutches of 3 produced about the same brood size at 4 wk as clutches of 2 did for the same period of time. Snowy egrets, Louisiana herons, and white ibises produced larger broods at 2 wk from larger clutches.

Egg Mortality—Nesting attempts observed and total eggs laid by the 9 species are in Table 6. Egg mortality is given for all nesting attempts in Table 7 and for nesting attempts hatching young in Table 8. Egg mortality, as a percentage of total eggs laid, was greater for nesting attempts failing to hatch young than losses from nesting attempts hatching young (Table 7).

Although faulty nest construction and pilfering of nesting material may have resulted in egg loss, the most important cause of egg mortality probably was avian predation. many eggshells with holes were found. Fish crows and boat-tailed grackles were seen regularly. These birds are known to take eggs and young birds. Wood storks probably had the greatest egg loss due to avian predation. Many empty eggs with holes were found below their nests.

Glossy ibis had the highest egg loss of any species failing to hatch young; only 9 of 23 nesting attempts hatched young (Table 7). In recent years numbers of glossy ibis in the central Florida area have declined. This decline may be a result of habitat destruction through drainage in the upper St. Johns River marshes (Sprunt, 1954). This area is about 7.5 km west of Moore Creek. Interaction with other nesters could also be a factor for their reduced reproductive success. Glossy ibis nested late when most other nesters were feeding young. Scarcity of nesting sites was indicated by the following observations: 10 of 23 glossy ibis nests were originally built by other birds; glossy ibis were the only birds to nest at the base of mangroves; and their nests were dispersed throughout the rookery.

Much unexplained egg mortality associated with hatching occurred in the 2 or 3 da preceding the first observation of young in the nest (Table 8). Jenni (1969) also observed greater egg losses on the day before and through hatching than losses during and preceding incubation at the Lake Alice colony.

MORTALITY OF YOUNG—Mortality of young is summarized in Table 9. Greatest mortality of cormorant nestlings was during the 2 wk following hatching. Nestlings died in the nest, probably from starvation, and many well-fed young fell from nests. On 2 occasions a nestling was knocked from the nest as the adult flew off. Starvation was the most probable cause of great blue heron nestling death. In all cases the smallest of the brood died first. Dead young were on the ground below the nest or enmeshed in the sides of the nest's cup. Some indication exists that great blue herons were more unsuccessful if their nests were near roosts and nest sites of wood storks. The storks laid eggs in one of the heron nests. It was not uncommon to find young of snowy egrets, Louisiana herons, and both ibises entangled in the mangrove branches; many of these died either from injuries or from starvation.

TABLE 7. Total egg loss for 9 species at Moore Creek, 1975.

Species	Egg Loss as Percent of Total Eggs Laid		
	Nests Without Hatched Young	Nests With Hatched Young	Total
Double-crested Cormorant	16.8	17.2	34.0
Anhinga	34.8	10.1	44.9
Great Blue Heron	21.8	13.0	34.8
Great Egret	27.6	4.6	32.2
Snowy Egret	8.9	6.0	14.9
Louisiana Heron	18.6	4.8	23.4
Wood Stork	46.6	13.6	60.2
Glossy Ibis	59.2	5.6	64.8
White Ibis	25.9	8.8	34.7

TABLE 8. Egg mortality in nesting attempts hatching young at Moore Creek, 1975.

	Egg Loss as Percent of Total Eggs Laid in Nesting Attempts Hatching Young			
Species	Disappeared During Incubation	Unexplained Hatching Loss[a]	Failed to Hatch	Total
Double-crested Cormorant	3.4	7.3	9.9	20.6
Anhinga	6.7	8.9	0.0	15.6
Great Blue Heron	2.7	11.1	2.8	16.6
Great Egret	0.9	0.9	4.5	6.3
Snowy Egret	1.1	4.9	0.5	6.5
Louisiana Heron	1.6	3.1	1.0	5.7
Wood Stork	4.2	19.1	2.2	25.5
Glossy Ibis	0.0	13.6	0.0	13.6
White Ibis	2.2	5.9	3.8	11.9

[a] Loss in this category occurred in the 2 or 3 da preceding the first observation of young in the nest.

TABLE 9. Mortality of young of 9 species at Moore Creek, 1975.

Species	Percent Mortality Biweekly				Total
	0-2	2-4	4-6	6-8	
Double-crested Cormorant (74 nests)	35.6	18.7	7.4	. . .	61.7
Anhinga (11 nests)	7.9	15.8	. . .	. . .	23.7
Great Blue Heron (12 nests)	33.3	23.4	3.2	0	59.9
Great Egret (45 nests)	16.5	21.4	. . .	. . .	37.9
Snowy Egret (60 nests)	15.8	. . .	. . .	. . .	15.8
Louisiana Heron (64 nests)	28.2	. . .	. . .	. . .	28.2
Wood Stork (16 nests)	25.5	0	. . .	. . .	25.5
Glossy Ibis (9 nests)	42.1	. . .	. . .	. . .	42.1
White Ibis (77 nests)	40.2	. . .	. . .	. . .	40.2

Comparison of nestling mortality at Moore Creek with published reports from other rookeries is possible for some species. Snowy egrets had a lower nestling mortality at 2 wk (15.8%) at Moore Creek than Teal (1965) observed at Sapelo Island, Georgia (62%) and Jenni (1969) reported at Lake Alice (28.1%). Maxwell and Kale (1977), studying at the Riomar Island herony, found 28.8% mortality for this species at 10 da after hatching. Louisiana heron nestling mortality was 57% at Sapelo Island. This is much higher than 28.2% found at Moore Creek. However, Jenni (1969) found slightly lower Louisiana heron nestling mortality (25.4%) than what was observed at Moore Creek. Maxwell and Kale (1977) found 20.5% mortality for this species at 10 da after hatching. Teal (1965) reported lower white ibis nestling mortality (28%) at Sapelo Island than was found at Moore Creek (40.2%).

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Biological Sciences

OCCURRENCE OF PARTIALLY STRIPED FORMS OF THE MANGROVE SNAKE *NERODIA FASCIATA COMPRESSICAUDA* KENNICOTT AND COMMENTS ON THE STATUS OF *N. F. TAENIATA* COPE

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Abstract: *The estuarine snake* (Nerodia fasciata compressicauda) *is an extremely variable mangrove inhabitant which can survive long periods of immersion in sea water (up to 99 da). There is an area of apparent intergradation with the sea water intolerant subspecies* N.f. pictiventris *on or near Chokoloskee Island in Collier County, Florida. The intergrades varied markedly among each other in coloration, yet all survived for prolonged periods in sea water (at least 30 da). Single litters from this population showed enormous pattern variation, including partially striped morphs very similar to* N.f. taeniata *from Volusia County, Florida. There are previous records of* taeniata*-like phenotypes from the Tampa Bay area and Cuba. It appears that* N.f. taeniata *should be relegated to synonymy with* N.f. compressicauda, *because neither coloration nor scale characters (numbers of subcaudals) can be used unequivocally as diagnostic characters. The greater frequency of partially striped forms in Volusia County is probably due to the utilization of salt marsh habitat there instead of mangroves. Thus, the superficial resemblance to* N.f. clarki *can be ascribed to habitat similarities, and not merely to possible contact with west coast salt marsh snakes during Pleistocene submergence of the intervening peninsula.*°

The North American Colubrid water snakes of the genus *Nerodia* (formerly *Natrix*, Rossman and Eberle, 1977) show early stages of the evolution of marine

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habits. Three species (*N. fasciata*, *N. sipedon*, *N. valida*) have developed sea water tolerant forms (Dunson, submitted). These are all coastal inhabitants and they probably lack salt glands which are found in the more specialized marine snakes of the families Hydrophiidae, Acrochordidae and Homalopsidae (Dunson, 1975; Dunson and Dunson, 1973, in press). However, they do have the low rates of exchange of sodium and water with sea water which are characteristic of most marine reptiles (Dunson, submitted). It is rather extraordinary that such physiological specialization could be present in 2 subspecies (*N. f. clarki* and *N. f. compressicauda*) and not in others (*N. f. pictiventris* and *N. f. confluens*). There is little doubt that extensive intergradation occurs in brackish water habitats where *N. f. clarki* and *N. f. confluens* meet (Pettus, 1956, 1958, 1963). An analogous situation occurs in salt marsh savannah sparrows (*Passerculus sandwichensis*). Some races have a greater ability to osmoregulate due to specialization in renal function (Cade and Bartholomew, 1959; Poulson and Bartholomew, 1962; Johnson, 1974).

During field and laboratory studies on mechanisms of salinity tolerance of *N. f. clarki* and *N. f. compressicauda* (Dunson, 1978, submitted), an unusual population of brackish water snakes was found in Collier County, Florida. Although *N. f. compressicauda* is known to be extremely variable in coloration, certain specimens from this locality seem to be intergrades with *N. f. pictiventris*, and others resemble *N. f. taeniata*. Because large numbers of *N. f. compressicauda* are rarely available from a single locality, a brief description of these specimens and the collection site will be given. A study of coloration and certain scale characters indicates that *N. f. taeniata* can not be considered a separate subspecies, but should be placed in synonymy with *N. f. compressicauda*.

METHODS—On 29 June 1977, snakes were collected in a small artificially constructed pond behind the Anglers Motel and Marina on Chokoloskee Island, Collier County, Florida. These animals totalling about 70, including progeny born subsequently in the lab, were utilized in various physiological studies (see Dunson, submitted, 1978) and then preserved and deposited in the U.S. National Museum (USNM numbers 207197-207268). Comparisons have been made with the syntypes of *N. f. taeniata* borrowed from the Academy of Natural Sciences of Philadelphia (ANSP 10903, 10904), a Cuban *N. f. compressicauda* (ANSP 19,488), and 7 *N. f. compressicauda* (USNM 207190-6) collected by P. Saber and E. Grosmaire near Tampa Bay, Pinellas County, Florida, on 2 March 1978. Salinity was measured with an American optical refractometer.

RESULTS—*N. f. compressicauda* is generally considered an uncommon snake, or else one which is very difficult to capture. The abundance of snakes found in a tiny brackish pond on Chokoloskee Island is unusual in my experience. Chokoloskee Island is only a few hundred meters from the mainland to which it is linked by a causeway across the intervening shallows. It is directly opposite the mouth of the Turner River. At the time of my visit the salinity of the mouth of the river was about 18‰ and of Chokoloskee Bay near the island about 22‰. The pond in which the snakes were captured was 14‰; it was not connected to the bay. The source of this lower salinity water was a well from which water was periodically pumped into the pond. Fish (*Gambusia*) were very numerous in the pond and a dense cover of matted vegetation hung down into the water around the edges. The pond was only a few meters from the edge of the bay, yet no snakes were seen in the bay at the same time that they were swarming in the pond. Snakes were only seen between dusk and about midnight, when collecting efforts ceased. It is worth noting that an incredible abundance of mosquitos also become evident at dusk, unfortunately coinciding with the activity pattern of the snakes!

As the snakes were being captured, it was immediately evident they exhibited a wide range of pattern variation. This is documented for a representative series in Figs. 1, 2, 3, and 4. Because *N. f. compressicauda* is such a variable form, it is difficult to characterize any phenotypes as "typical." However, the patterns shown in Fig. 1 would not be considered unusual in my experience.

There were also many snakes with variable amounts of striping on the head and neck in the Chokoloskee Island group (Fig. 2). These are also known from other areas (Barbour and Noble, 1915). In fact Carr and Goin (1942) commented on a partially striped Cuban specimen (ANSP 19,488) which resembled *N. f. taeniata*. I have examined 7 *N. f. compressicauda* recently collected at a single locality near Tampa Bay (Placido Bayou in St. Petersburg) in high salinity water (25‰). This small group illustrates extremely well the remarkable diversity in color and pattern of single populations of this subspecies. Two of the snakes were red phase, 1 was light tan, and 4 were grayish-brown with crossbars. Four of the snakes had prominent neck stripes. Similarly striped specimens have also been collected in Monroe County (on Summerland Key and islands in Florida Bay). The significance of *taeniata*-like phenotypes from many parts of the range of *N. f. compressicauda* seems to have been overlooked. One problem is that *N. f. taeniata* is itself a rather variable subspecies. I examined the *taeniata* syntypes (ANSP 10903, 10904) and compared them with the striped forms from Chokoloskee Island (Fig. 3). A photograph (Fig. 5) of *N. f. taeniata* from R. Conant's files is also shown for comparison. Cope (1895) in his original description of "*Natrix compressicauda taeniata*," emphasized the presence of "two longitudinal stripes on the greater part of the length." Carr and Goin (1942) subsequently separated *taeniata* from *compressicauda* on the basis of "longitudinal stripes, the smaller size, and the greater number of subcaudals." An examination of Figs. 2 and 3 should provide convincing evidence that a single population of *compressicauda* (even a single brood in one case) can include specimens of many degrees of dorsal striping, including one with essentially complete striping. The stripes are more obvious in the *N. f. taeniata* syntypes because of the yellowish background. The tendency of the stripes to break up into blotches is similar in both forms. In the *taeniata* syntype ANSP 10903, the left dorsolateral dark stripe continues for 63% of the snout vent length (SVL) before breaking up; on the right side it breaks into blotches at about 66% of the SVL. In the other syntype (ANSP 10904) the dorsal stripes are shorter, about 34 and 50% of the SVL. In a Cuban *N. f. compressicauda* (ANSP 19,488) the 2 dorsolateral dark

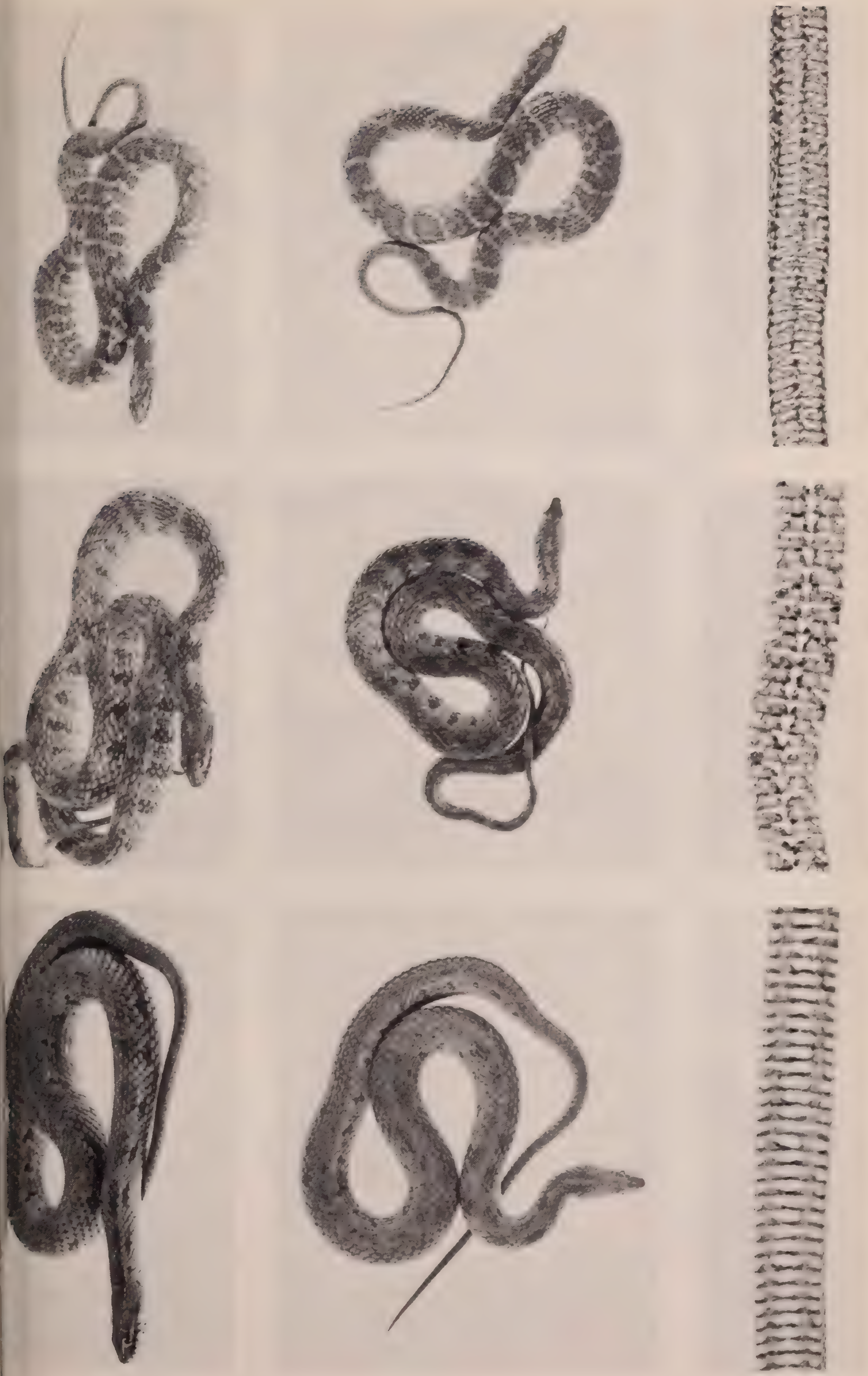

FIG. 1. Chokoloskee Island *Nerodia fasciata* of typical *compressicauda* appearance. Lateral, dorsal and ventral views are shown for 3 specimens from the top to the bottom. There are no neck stripes.

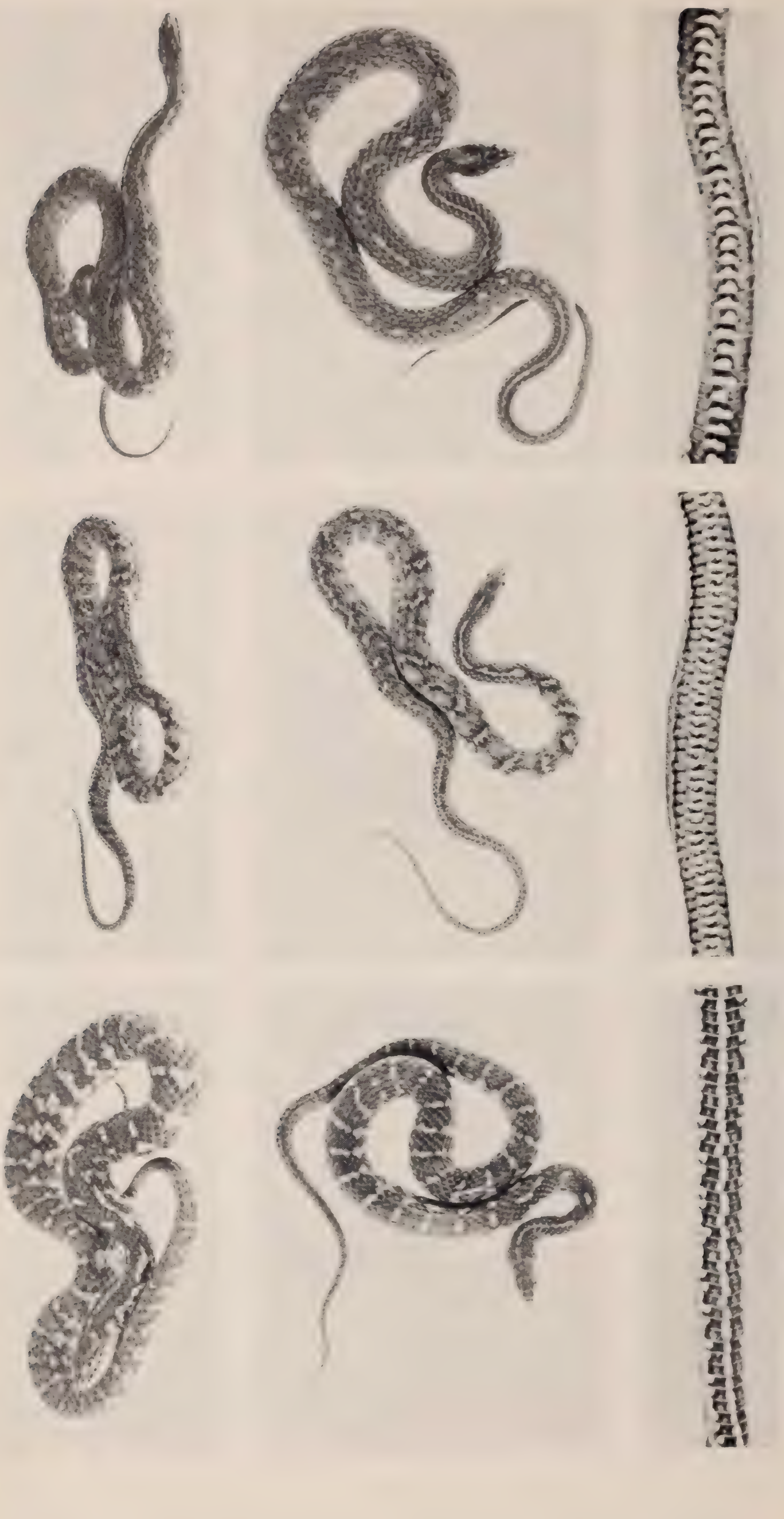

Fig. 2. Three Chokoloskee Island *Nerodia fasciata compressicauda* which resemble *N. f. taeniata*. Notice the stripes on the neck and the mid-ventral white spots.

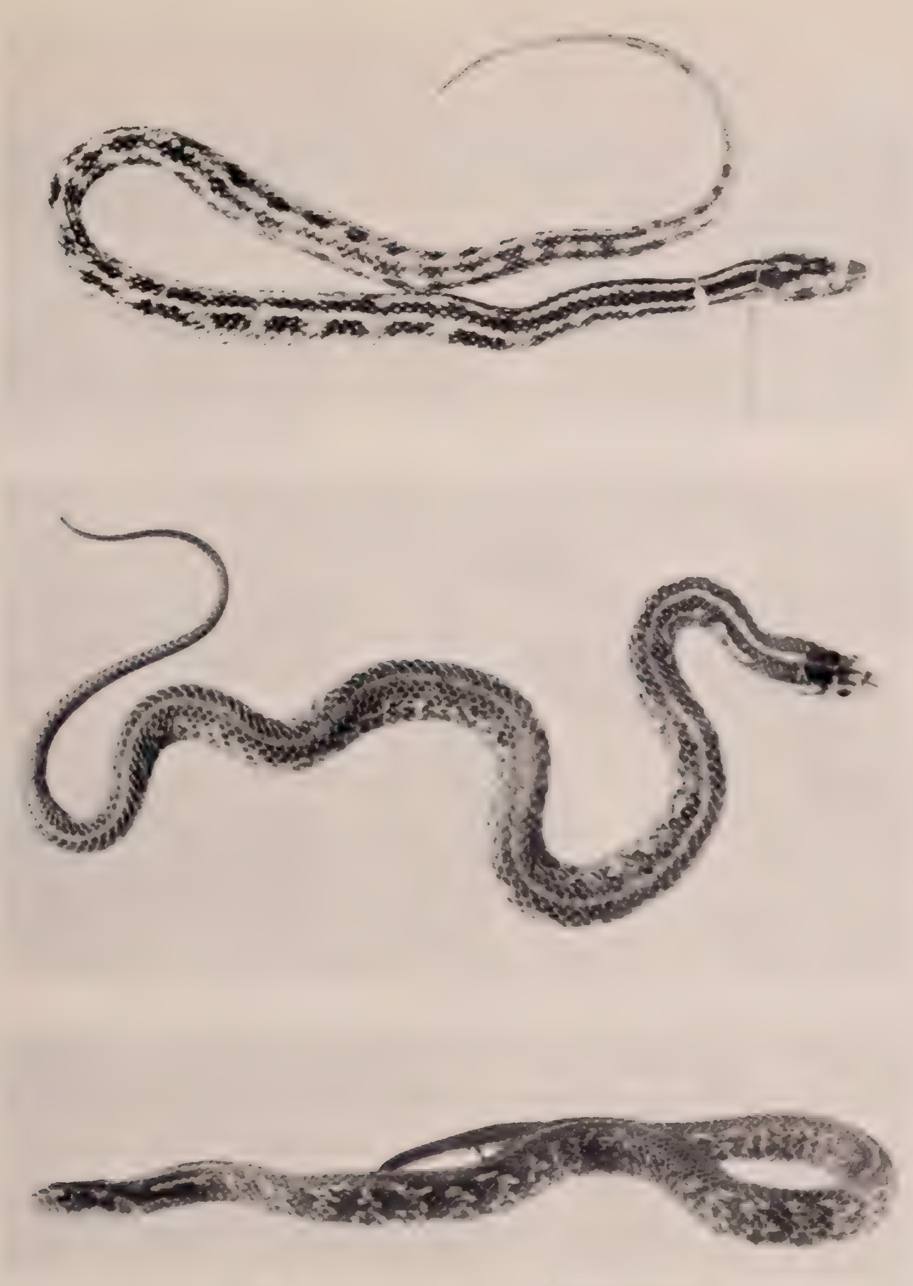

FIG. 3. Upper: A syntype of *N. f. taeniata* Cope (ANSP 10904) from Volusia County, Florida (National Gardens). Note that the dark stripes break up into blotches before the midbody is reached. Middle and lower: Top and side views of a juvenile *N. f. compressicauda* from a brood produced in captivity by a female captured in Collier County, Florida (Chokoloskee Island). There is a light dorsal stripe continuous the entire length of the body (separating two dark "stripes"). A dark lateral neck stripe breaks up into dark blotches (or diamonds) that continue along the sides of the entire body.

stripes extend for about 30% of the SVL. Four of 7 *N. f. compressicauda* from Placido Bayou (Pinellas County) had neck stripes. In these specimens the dark dorsolateral stripes broke up into blotches at approximately 10%, 10%, 20% and 25% of the SVL.

A comparison of the ventral and subcaudal scale counts for *N. f. taeniata* and *N. f. compressicauda* is in Table 1. Numbers of ventrals were similar in all cases. The supposed greater number of subcaudals in *N. f. taeniata* was not substantiated in comparison with the Chokoloskee Island *N. f. compressicauda*. In fact the latter had values virtually identical with those of *N. f. taeniata* (Table 1).

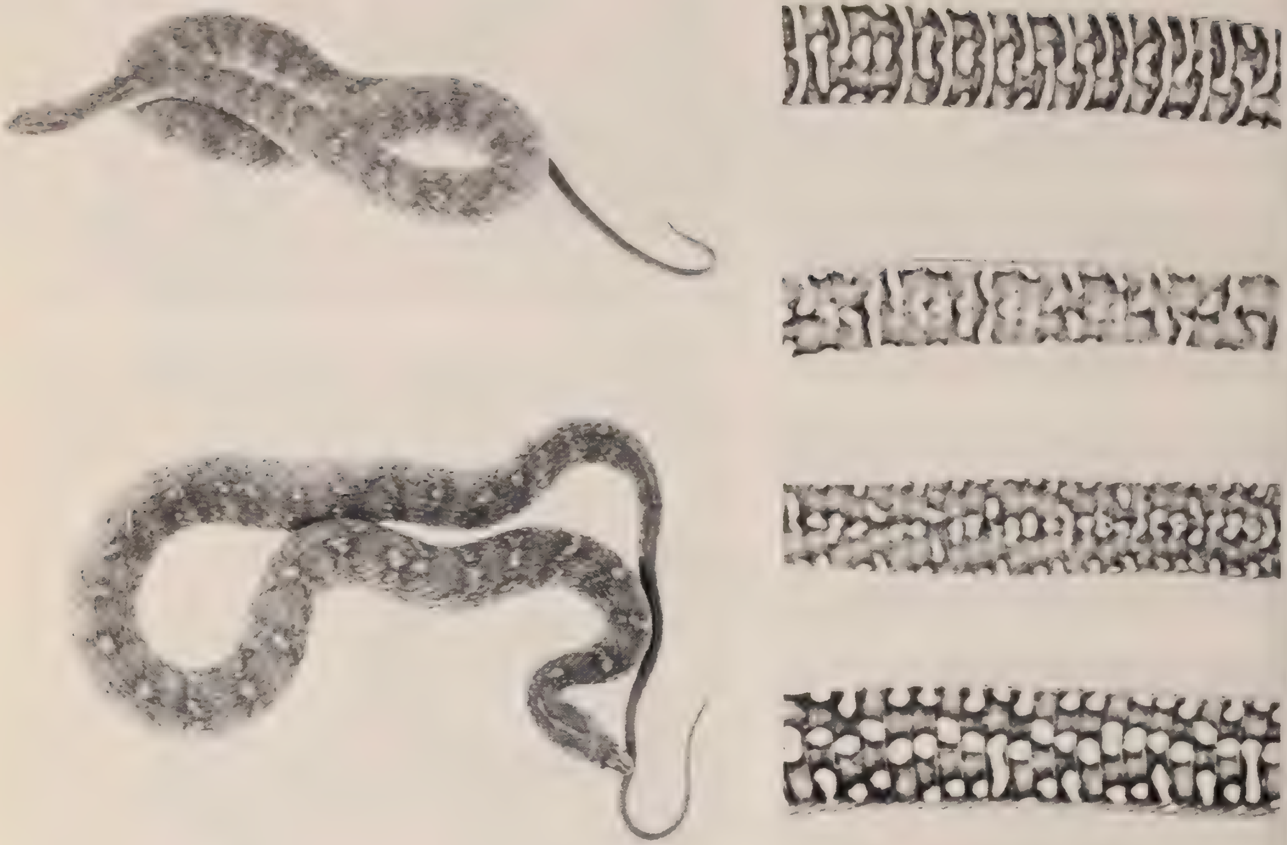

FIG. 4. Some *Nerodia fasciata* which resemble *N. f. pictiventris*, from the same Chokoloskee Island pond as those shown in Figs. 1 and 2. Lateral and dorsal views of a representative specimen are shown on the left. The top ventral view on the right belongs to this snake. The others are of additional specimens of similar dorsal coloration. Note the tendency towards white mid-ventral spotting.

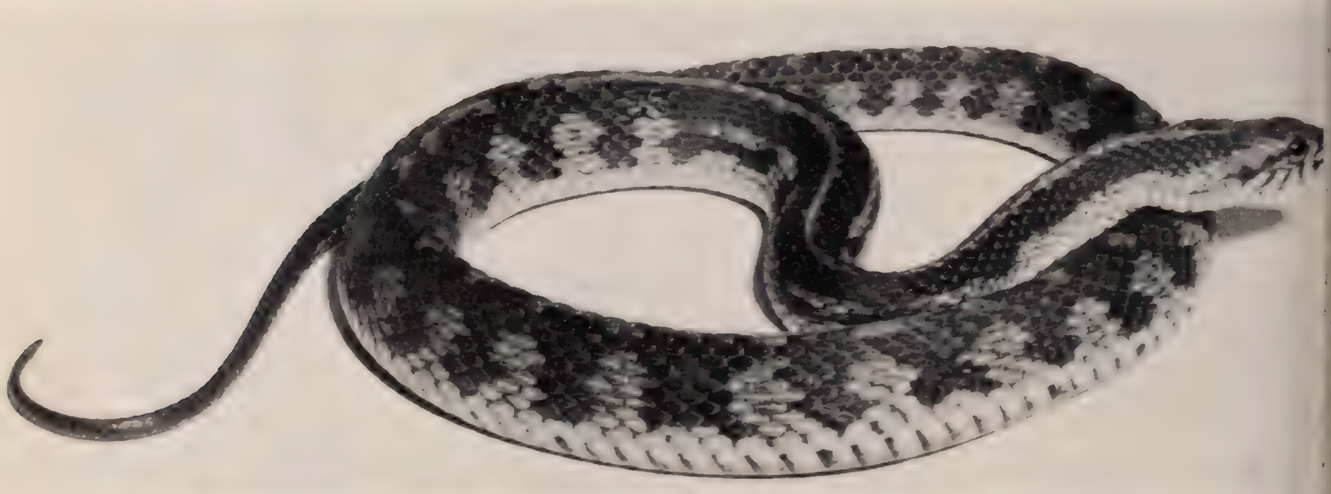

FIG. 5. A Brevard County *N. f. taeniata* collected near Cocoa, Florida, by Lon Ellis in 1965. Note the close similarity in pattern to the Collier County specimen shown in Fig. 3. Photographed by Isabelle H. Conant and kindly made available by Roger Conant.

TABLE 1. Scale counts on *N. f. compressicauda* and *N. f. taeniata*. Means ±S D with ranges in parenthesis. SVL is snout vent length in mm.

	Males				Females			
Specimens	N	SVL	Ventrals	Subcaudals	N	SVL	Ventrals	Subcaudals
N. f. taeniata								
A. From Carr and Goin, 1942; N of 13 for males and females combined								
	–	–	129	83	–	–	130	74
			(127–131)	(76–88)			(128–131)	(72–76)
B. Syntypes ANSP 10903, 10904 (not sexed)								
	1	167	129	85				
	1	280	130	78				
N. f. compressicauda								
A. From Carr and Goin, 1942; N of 10 for males and females combined								
	–	–	129	60	–	–	127	71
			(129–130)	(50–80)			(123–130)	(62–76)
B. From Collier County Florida, Chokoloskee Island.								
	4	411	126	82	7	564	129	74
		±40	±2	±3		±84	±2	±2
			(124–128)	(79–87)			(126–132)	(71–77)
C. From Cuba, ANSP 19,488 (not sexed)								
	1	–	130	75				
D. From Placido Bayou, Pinellas County Florida (Saber and Grosmaire, collectors)								
	3	467	132	80				
		±37	±4	±3				
			(128–135)	(77–82)				

The brackish water snakes collected from a single small pond on Chokoloskee Island have so far been referred to *N. f. compressicauda*. Yet there were some snakes from this locality remarkably similar to the fresh-water race *N. f. pictiventris* (Fig. 4). These are believed to be intergrades between *compressicauda* and *pictiventris*. However, it is important to note that all of the phenotypes survived equally well when placed in sea water. Physiologically, the population is *N. f. compressicauda*.

DISCUSSION—*N. f. taeniata* was first described by Cope (1895) as *Natrix compressicauda taeniata*. Barbour and Noble (1915) offered persuasive evidence that only 1 race of *Natrix compressicauda* should be recognized. However, Carr and Goin (1942) reestablished the Volusia County race as *Natrix sipedon taeniata*. Conant (1963) has subsequently placed this form in the *Natrix fasciata* group. A recent study (Kochman, 1977) has characterized *N. f. taeniata* as "highly problematical." One of the major problems in evaluating the status of the form is that the geographic pattern of variation in *N. f. compressicauda* is so poorly known. The diversity of color patterns of *N. f. compressicauda* caused great confusion among early herpetologists. Cope (1900) listed 5 forms equivalent to our present-day concept of this single subspecies (*N. usta*, *N. c. compressicauda*, *N. c. walkerii*, *N. c. obscura*, *N. c. compsolaema*). Barbour and Noble (1915) relegated the latter 4 subspecies to a single race. *N. usta* must also be considered synonymous because it was reported from Key West, where only *N. f. compressi-*

cauda is found. It should be mentioned that Cope's holotype of *N. c. compsolaema*, that Barbour and Noble (1915) reported was lost, is in Philadelphia (ANSP 6645). I discovered it while looking for Cope's *taeniata* types.

A key feature of the evaluation of the relative status of *N. f. taeniata* and *N. f. compressicauda* is the remarkable variability of the latter subspecies, even within a single brood. This situation has been documented by Clay (1938), Swanson (1948) and Bishop (1940). Clay (1938) mentioned that the "presence of two or four longitudinal stripes is not unusual, especially in the neck region." Several polymorphic broods were observed by Bishop (1940). The lack of any systematic geographic trends in pattern variation was one of Barbour and Noble's (1915) strongest arguments against taxonomic splitting of this group. It seems likely that *N. f. taeniata* is also quite variable in coloration, although there are few published data on this point. Rick Demmer, who has probably had the most extensive contact of any present-day field worker with this form, has not been successful in finding a "pure" population (pers. comm.).

Demmer agrees that the snakes in Fig. 2 closely resemble *N. f. taeniata* (intergrades with *pictiventris*?) from the Turnbull Creek locality which he and Ken Richmond discovered. This is the same site subsequently used by Kochman (1977). Considerable integradation of *N. f. taeniata* with *N. f. pictiventris* and *N. f. compressicauda* is believed to occur (Kochman, 1977; Neill and Demmer, pers. comm.). The tendency for greater degrees of striping, and the generally lighter color may be attributed to selection pressures in marsh rather than in mangrove habitat (where *N. f. compressicauda* is most common). The lack of any consistent trends in subcaudal scale numbers also indicates there is not sufficient isolation of the Volusia County population to merit subspecific designation. An analogous situation may occur in the king snake (*Lampropeltis getulus*) where there is enormous variation in pattern in different parts of the U.S. and many of these variants are recognized as subspecies. However in California, striped and ringed phenotypes are both considered *L. g. californiae* because of the presence of many individuals of intermediate coloration (Stebbins, 1954). The supposed distinction of *N. f. taeniata* has been perpetuated because few data have been available on pattern variation, because information on the degree of striping well known to be present in *N. f. compressicauda* has been ignored (Cochran and Goin, 1970, state incorrectly that *N. f. compressicauda* "lacks stripes"), and because of speculation on the relationship between *N. f. taeniata* and *N. f. clarki*. Carr and Goin (1942) were apparently the first to suggest that *N. f. taeniata* retains striping derived from interbreeding with *N. f. clarki* during Pleistocene changes in sea level. Kochman (1977) suggests that "*N. f. taeniata* may actually represent a relictual hybrid swarm dating back to Pleistocene contact of *clarki* and *compressicauda* prototypes." It is probably more appropriate to suggest that such a process involved *pictiventris* and *compressicauda*. Continued genetic interchange with *pictiventris* and *compressicauda* certainly seems to be occurring at present. However, it seems unnecessary to invoke the genetic influence of *clarki* because *taeniata*-like patterns have now been found in *compressicauda* populations in Collier County, far from any presumed *clarki* influence. The *taeniata* specimen pictured by Wright and Wright (1957) from a glasswort flat at Mosquito Inlet is indistinguishable from certain *compressicauda* I have collected.

An additional factor to be considered is the modifying effect of the gradual change from a mangrove to a salt marsh environment. On the west coast of Florida *compressicauda* and *clarki* intergrade in Pinellas County (Neill, pers. comm.) perhaps due to the intermixing of mangrove and salt marsh in this area. Neill also reports considerable intermixing of *pictiventris*, *compressicauda* and *taeniata* on the east coast of Florida, in northern Brevard County. Kochman's (1977) study site at Turnbill Creek (Volusia County just north of Brevard County) was an area of extensive intergradation between *pictiventris* and *taeniata*. Thus, the tendency for striping already present in the *compressicauda* population could have been selectively increased due to the prevalence of marsh rather than mangrove habitats in Volusia County. This local change in the relative frequency of striping has probably been subject to continual dilution from inland *pictiventris* in areas of brackish habitat and from coastal *compressicauda* to the south. Considerable field work in Brevard and Volusia Counties will be necessary to confirm this hypothesis. However, it seems the most reasonable explanation of the striking similarity in phenotype between "*taeniata*" from Volusia County and some forms of *compressicauda* from Collier and Monroe Counties.

N. f. taeniata is currently recognized as an endangered subspecies by the State of Florida and as a threatened subspecies by the U.S. Dept. of Interior. Modification of its taxonomic status as suggested above should somewhat relieve concern for survival of salt water snakes in Florida as classified under the subspecific designation *compressicauda*. However populations of *compressicauda* along the east coast especially deserve protection. Due to their apparent low population levels and the limited coastal habitat available, it would not be inappropriate to provide protection throughout the entire range of *compressicauda*.

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QUARTERLY JOURNAL OF THE FLORIDA ACADEMY OF SCIENCES

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Biological Sciences

A COMPARISON OF FISH COMMUNITIES IN VEGETATED AND BEACH HABITATS[1]

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ABSTRACT: *We compared fish populations in Lake Conway, Florida by 3 methods for species abundance, composition, and species diversity. Sampling was from May through September 1976 in both vegetated and man-made beach habitats. Eleven species had strong affinities with vegetation, whereas 7 species were most common on beaches. The ichthyofauna associated with vegetation represents a climax and was more unique, more diverse, more evenly distributed in terms of individuals of each species, and more productive in terms of biomass. Beach fishes represent a seral community which is typified by a less distinct and diverse, but more numerous assemblage.*[°]

DENSE STANDS of emergent aquatic vegetation are common in many central Florida lakes. These stands sometimes conflict with recreational pursuits and reduce property values. As a result, many property owners remove this vegetation to create sand-bottomed beaches. In heavily populated suburbs this practice may remove as much as 75% of the total shoreline vegetation.

Shallow littoral zones with dense stands of rooted emergent vegetation are important ecologically for the production of fish and invertebrates (Barnett and Schneider, 1974; Wegener et al., 1973). Emergent plants, by inducing chemical and physical changes in the aquatic environment, also create a more diversified habitat (Gaudet, 1974). We compared species abundance, composition, and diversity of shore zone fishes collected in vegetated and artificial beach habitats in Lake Conway, Florida.

MATERIALS AND METHODS—Our research was conducted in the Lake Conway chain of lakes near Orlando, Florida. This system is part of the Kissimmee River drainage and totals 728 ha. The shoreline has been altered by urbanization and associated vegetation removal; some areas still have a narrow fringe of cattail

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(*Typha latifolia*), maidencane (*Panicum hemitomon*), torpedo grass (*P. repens*), and lake rush (*Fuirena scirpoides*). Dominant submergent vegetation includes eelgrass (*Vallisneria americana*), nitella (*Nitella megacarpa*), Illinois pondweed (*Potamogeton illinoensis*), and hydrilla (*Hydrilla verticillata*). The substrate is sandy, except in areas of extremely dense vegetation where organic detritus has built up. The bottom contours are rather steep in many areas.

We sampled both vegetated and artificial beach littoral habitats. Samples were taken from May through September 1976 by seine, Wegener ring (Wegener et al., 1973), and electroshocker. Six fixed stations were established for each gear type and sampled monthly. Two Wegener ring samples were taken at each station in shallow, heavily vegetated areas. A 6.1 m seine collection of 5 hauls was made in beach zones adjacent to Wegener ring sites. A 30 min nighttime electrofishing sample was taken in both vegetated and beach areas at each station.

A chi-square test was used on frequency of occurrence data from electrofishing beach and vegetation samples to assess statistically significant differences in occurrence of each species between habitats. Similarly, a t-test was used on the electrofishing numeric and biomass data.

Betchel and Copeland (1970), applying the Shannon-Weaver diversity index to Galveston Bay fish data, determined that indices based on pooled data were more representative of an area than the mean of indices based on single collections. For this reason, monthly pooled data for each gear type was subjected to analysis by 3 species diversity indices.

The Shannon-Weaver index (Shannon and Weaver, 1963) was selected as the first method of analysis. This index is sensitive to both species richness and evenness and is calculated according to the following formula: $H = \frac{-n_i}{N} \log_{10} \frac{n_i}{N}$, where n_i is the number of individuals in the i^{th} species and N is the total number of individuals. This index is reasonably independent of sample size and normally distributed.

Following Margalef (1958), the species richness aspect of diversity was calculated according to $D = S\text{-}1/\log_{10}N$, where S is the number of species and N is the total number of individuals.

The evenness index of Pielou (1966) was also calculated: $J = H/Hmax = H/Log_{10}S$, where H is the Shannon-Weaver index value and S is the number of species.

ABUNDANCE—Numerical abundance of fishes collected from both habitats is in Table 1. Of the species collected by electroshocking in both beach and vegetation stations, *Dorosoma petenense* (threadfin shad), *Notropis petersoni* (coastal shiner), *Fundulus seminolis* (Seminole killifish), *Labidesthes sicculus* (brook silverside), *Lepomis macrochirus* (bluegill), *Lepomis microlophus* (redear sunfish), and *Micropterus salmoides* (largemouth bass) were statistically more abundant in beach areas than in vegetated areas (Table 2). Conversely, *Lepisosteus platyrhynchus* (Florida gar), *Amia calva* (bowfin), *Esox niger* (chain pickerel), and

Pomoxis nigromaculatus (black crappie) were statistically more common in vegetated sites as compared to beach sites. Other species taken in both habitats either did not show a statistical preference for either habitat or were encountered in such small numbers that statistical methods were not applicable. The total number of fish collected was statistically more abundant in beach areas than in the vegetated habitats.

Difference in abundance of fishes collected by the Wegener ring and seine were not statistically analyzed due to the difference in sampling techniques; however, a comparison can be made of relative abundance of fishes in each habitat according to percentage composition. Of the species collected by these methods, *Fundulus chrysotus* (golden topminnow), *Lucania goodei* (bluefin killifish), and *Gambusia affinis* (mosquitofish) were more common in vegetated than in beach stations (Table 1). However, *Notropis petersoni, Labidesthes sicculus, Lepomis macrochirus, Lepomis microlophus*, and *Micropterus salmoides* were more bundant in beach habitats.

Biomass—Average monthly biomass for each gear type is in Table 1. *Lepisosteus platyrhynchus, Amia calva, Ictalurus natalis* (yellow bullhead), *Lepomis gulosus* (warmouth), and *Micropterus salmoides* were statistically more abundant in electroshocking samples taken in vegetated zones (Table 2). In contrast, *Notropis petersoni, Fundululus seminolis*, and *Labidesthes sicculus* exhibited a statistically greater biomass in beach samples as compared to vegetation. The total biomass collected in vegetated sites was greater than that found in beach stations.

Notropis petersoni, Fundulus chrysotus, Lucania goodei, Gambusia affinis, and *Micropterus salmoides* had higher percentage compositions of biomass in the Wegener ring samples taken in vegetation as compared to seine collections in non-vegetated sites (Table 1). *Fundulus seminolis, Labidesthes sicculus, Lepomis macrochirus*, and *Lepomis microlophus* had greater biomass percentages in seine collections as opposed to Wegener ring samples.

Frequency of Occurence—The number of times each species was collected for each gear type is in Table 1. In electroshocking samples, *Dorosoma petenense, Fundulus seminolis*, and *Labidesthes sicculus* were encountered a statistically greater number of times in beach collections as compared to vegetation samples (Table 2). *Notemigonus crysoleucas* (golden shiner) and *Notropis petersoni* were encountered more frequently in beach habitats, although this is not significant statistically. Only *Lepomis gulosus* and *Lepomis punctatus* (spotted sunfish) significantly preferred the vegetated habitats. However, *Lepisosteus plathrhynchus, Esox niger, Erimyzon sucetta* (lake chubsucker), *Enneacanthus gloriosus* (bluespotted sunfish), and *Pomoxis nigromaculatus* were collected more regularly in the vegetated stations than in the beach areas. *Amia calva, Ictalurus nebulosus* (brown bullhead), *Ictalurus natalis*, and *Gambusia affinis* were not found in the beach habitats.

All species collected in beach seines were taken in the vegetated Wegener ring samples; however, *Ictalurus nebulosus, Jordanella floridae* (flagfish), *Heterandria formosa* (least killifish), *Enneacanthus gloriosus*, and *Etheostoma fusi-*

TABLE 1. Catch per unit effort in number of individuals (A) and biomass in grams (B) and frequency of occurrence (C) of fishes collected by electrofishing (E), seine (S), and Wegener ring (WR) in vegetated and beach habitats in Lake Conway, May through September 1976. I and II represent the numerical value and percent composition, respectively.

		Beach				Vegetation			
		E		S		E		WR	
		I	II	I	II	I	II	I	II
Lepisosteus osseus	A	0.1	.03						
(longnose gar)	B	3.1	0.30						
	C	1.0	5.55						
Lepisosteus platyrhincus	A	0.3	.08			1.3	.96	0.1	.12
(Florida gar)	B	201.3	2.12			621.6	4.55	0.1	.24
	C	3.0	16.67			10.0	55.55	2.0	3.33
Amia calva	A					0.4	.29		
(bowfin)	B					1251.9	9.16		
	C					3.0	16.67		
Dorosoma cepedianum	A	0.4	.11			0.1	.07		
(gizzard shed)	B	333.4	3.52			72.2	.53		
	C	1.0	5.55			1.0	5.55		
Dorosoma petenense	A	41.7	11.42			7.2	5.31		
(threadfin shad)	B	170.1	1.80			44.3	.32		
	C	16.0	88.88			12.0	66.67		
Esox niger	A	2.0	.55			6.6	4.87		
(chain pickerel)	B	595.8	6.29			1536.8	11.25		
	C	10.0	55.55			14.0	77.78		
Notemigonus crysoleucas	A	3.2	.88			2.0	1.47		
(golden shiner)	B	108.7	1.15			179.3	1.31		
	C	10.0	55.55			9.0	50.00		
Notropis petersoni	A	3.0	.82	3.0	4.39	0.1	.07	1.1	4.06
(coastal shiner)	B	3.6	.04	1.9	.46	0.1	.01	0.7	2.85
	C	6.0	33.33	6.0	20.00	1.0	5.55	13.0	21.67
Erimyzon sucetta	A	0.7	.19			0.8	.59		
(lake chubsucker)	B	253.6	2.68			393.5	2.88		
	C	3.0	16.67			4.0	22.22		

Ictalurus natalis	A					0.3	.22		
(yellow bullhead)	B					62.3	.46		
	C					3.0	16.67		
Ictalurus nebulosus	A					0.4	.29	0.1	.36
(brown bullhead)	B					111.2	.81	0.1	.26
	C					3.0	16.67	4.0	6.67
Fundulus chrysotus	A			0.1	.14			0.6	2.06
(golden topminnow)	B			0.2	.05			0.6	2.68
	C			1.0	3.33			11.0	18.33
Fundulus seminolis	A	15.8	4.32	58.32	84.22	0.7	.52	2.3	8.54
(Seminole killifish)	B	102.4	1.08	265.8	64.31	3.4	.02	2.9	12.32
	C	16.0	88.88	27.0	90.00	3.0	16.67	27.0	45.00
Jordanella floridae	A							0.1	.06
(flagfish)	B							0.1	.01
	C							1.0	1.67
Lucania goodei	A			0.2	.28	0.2	.15	13.2	48.58
(bluefin killifish)	B			0.1	.02	0.1	.01	3.0	12.86
	C			5.0	16.67	1.0	5.55	37.0	61.67
Gambusia affinis	A			0.3	.43	0.2	.15	13.2	48.53
(mosquitofish)	B			0.1	.02	0.1	.01	3.0	12.86
	C			5.0	16.67	1.0	5.55	42.0	70.00
Heterandria formosa	A							0.1	.05
(least killifish)	B							0.1	.01
	C							4.0	1.67
Labidesthes sicculus	A	30.19	8.46	0.3	4.63	2.2	1.62	0.1	.06
(brook silverside)	B	28.70	.30	0.3	0.70	1.6	.01	0.1	.05
	C	15.00	83.33	6.0	20.00	6.0	33.33	1.0	1.67
Enneacanthus gloriosus	A	0.10	.03			0.3	.22	0.5	1.70
(bluespotted sunfish)	B	0.10	.01			0.4	.01	0.6	2.32
	C	1.00	5.55			2.0	11.11	7.0	11.67
Lepomis gulosus	A	0.20	.05			4.7	3.47	0.5	1.94
(warmouth)	B	0.20	.01			98.1	.72	2.5	10.67
	C	1.00	5.55			10.0	55.55	7.0	11.67

TABLE 1. (Continued)

		Beach				Vegetation			
		E		S		E		WR	
		I	II	I	II	I	II	I	II
Lepomis macrochirus	A	177.70	48.64	3.2	3.81	72.2	53.24	0.5	2.00
(bluegill)	B	3151.80	32.28	60.3	14.59	2138.7	15.65	3.1	13.38
	C	18.00	100.00	15.0	50.00	18.0	100.00	8.0	13.33
Lepomis marginatus	A	0.10	.03			0.2	.15		
(dollar sunfish)	B	0.40	.01			0.8	.01		
	C	1.00	5.55			1.0	5.55		
Lepomis microlophus	A	58.6	16.04	2.6	1.83	19.60	14.45	0.30	1.10
(redear sunfish)	B	2139.3	22.59	71.8	17.37	1298.90	9.51	0.70	3.02
	C	17.0	94.44	9.0	30.00	17.00	94.44	4.00	1.67
Lepomis punctatus	A	0.1	.03			1.20	.88		
(spotted sunfish)	B	6.3	.07			26.00	.19		
	C	1.0	5.55			7.00	38.85		
Micropterus salmoides	A	29.9	8.18	1.3	1.88	14.10	10.49	.04	1.57
(largemouth bass)	B	2332.0	24.62	12.8	3.10	5562.40	40.71	0.80	3.41
	C	18.0	100.00	14.0	46.66	18.00	100.00	18.00	30.00
Pomoxis nigromaculatus	A	0.4	.11			1.00	.74		
(black crappie)	B	40.0	.42			25.98	1.90		
	C	2.0	11.11			8.00	44.44		
Etheostoma fusiforme	A	0.1	.03					1.70	6.12
(swamp darter)	B	0.1	.01					0.80	3.28
	C	1.0	5.55					21.00	35.00
Totals	A	365.3		69.1		135.8		27.50	
	B	9470.9		413.3		135.6		24.00	

forme (swamp darter) were not taken in the seine samples (Table 1). *Notropis petersoni, Fundulus chrysotus, Lucania goodei, Gambusia affinis,* and *Lepomis gulosus* had higher percent occurrences in Wegener ring collections, while *Fundulus seminolis, Labidesthes sicculus, Lepomis macrochirus, Lemopis microlophus,* and *Micropterus salmoides* were encountered more frequently in seine collections.

TABLE 2. Species showing statistically significant greater numbers and weight as determined by a t-test and frequency of occurrences as determined by a chi-square test for electroshocking samples.

	Beach			Vegetation		
	No.	Wt.	Freq.	No.	Wt.	Freq.
Lepisosteus platyrhincus				°°	°	
Amia calva				°	°	
Dorosoma petenense	°		°			
Esox niger				°		
Notropis petersoni	°	°				
Ictalurus natalis					°°	
Ictalurus nebulosus				°		
Fundulus seminolis	°°	°°	°°			
Labidesthes sicculus	°	°	°			
Lepomis gulosus				°	°	°
Lepomis macrochirus	°					
Lepomis microlophus	°					
Lepomis punctatus				°		°°
Micropterus salmoides	°				°	
Pomoxis nigromaculatus				°°		
Total	°°					

° and °° indicate significance at the .05 and .01 levels.

DIVERSITY—The number of species and 3 diversity indices are presented monthly for each gear type in Table 3. In all cases, techniques sampling vegetation (electroshocking -vegetation, Wegener ring) gave higher Shannon-Weaver, species richness, and species evenness values than beach samples (electroshocking-beach, seine). Electroshocking-vegetation gave the highest Shannon-Weaver value with .69 (.68-.70), followed by Wegener ring with .67 (.60-.75), electroshocking-beach with .56 (.52-.65), and seine with .31 (.17-.46). As with Shannon-Weaver diversity, species richness diversity reached highest values in electroshocking-vegetation (6.86), followed by Wegener ring (4.81), electroshocking-beach (4.37), and seine (2.56). Wegener ring samples gave the highest species evenness diversity with .62, followed by electroshocking-vegetation with .57; electroshocking-beach (.52) and seine (.40) had the lowest values.

Overall, a total of 26 species was collected in the Lake Conway shore zone rom May through September 1973 (Table 1). Twenty-three species were colected by electrofishing. Electrofishing in beach areas yielded 19 species, whereas 21 species were taken in Wegener ring samples and 9 by 6.1 m seine.

DISCUSSION—A total of 16 species was associated with vegetated habitats in Lake Conway, having been encountered only or in greater numbers in vegetation amples. These species included *Ami calva, Lepisosteus platyrhynchus, Esox*

TABLE 3. Variation in number of species and species diversity indices for monthly pooled samples for each gear type.

	May	June	July	Aug	Sept	Mean
Wegener ring						
Number of species	10	10	13	12	14	11.8
Shannon-Weaver	.60	.73	.60	.69	.75	.67
Species richness	4.09	4.18	5.40	5.44	4.93	4.81
Species evenness	.60	.66	.57	.64	.64	.62
Seine						
Number of species	7	5	6	6	8	6.4
Shannon-Weaver	.17	.18	.32	.44	.46	.31
Species richness	2.34	1.93	2.39	2.73	3.43	2.56
Species evenness	.21	.26	.45	.57	.51	.40
Electroshocking-vegetation						
Number of species			21	18	16	18.3
Shannon-Weaver			.70	.68	.70	.69
Species richness			7.73	6.76	6.11	6.87
Species evenness			.56	.57	.59	.57
Electroshocking-beach						
Number of species			14	13	13	13.3
Shannon-Weaver			.65	.52	.52	.56
Species richness			4.68	4.20	4.24	4.37
Species evenness			.56	.50	.50	.52

niger, Erimyzon sucetta, Ictalurus natalis, Ictalurus nebulosus, Gambusia affinis, Heterandria formosa, Lucania goodei, Jordanella floridae, Fundulus chrysotus, Enneacanthus gloriosus, Lepomis gulosus, Lepomis punctatus, Pomoxis nigromaculatus, and *Etheostoma fusiforme*. The following species were more common in beach collections: *Dorosoma petenense, Notropis petersoni, Fundulus seminolis, Labidesthes sicculus, Lepomis macrochirus, Lepomis microlophus*, and *Micropterus salmoides*. The other species found in shoreline collections were either encountered in such small numbers that basic habitat preferences could not be established or they showed no clear preference for habitat.

The beach community is characterized by the numerical distribution of individual species. This assemblage, however, is composed of transients from adjacent habitats and a small group of ubiquitous species appearing in large numbers. The 7 most abundant beach fishes greatly dominated beach collections, representing 99.1% of the total number in seines and 97.9% in electroshocking. The remaining species collected in beach sites were rarely encountered. Conversely, the assemblage of species associated with vegetated habitats is ecologically distinct; most species are either restricted to these habitats or only common there.

Because of the greater efficiency of electrofishing in beach zones and the migration of small centrarchids and forage fish to barren beaches at night, the number of fish per collection was enhanced in beach samples. In terms of biomass, however, electrofishing was more productive in the vegetative habitats than in the beach ones. Thus, smaller individuals utilized beach areas at night as compared to vegetated habitats.

A consistent trend in our data is the greater number of species found in vegetated samples as compared to beach collections. This trend resulted in a cumulative total of 26 species taken in vegetated sites and 22 species collected in beach stations. This species differential would have been greater except for the presence of several vegetative-associated species taken in small patches of vegetation in beach stations.

The foregoing analyses consider the number of species and the number of individuals as separate entitites but do not account for community structure, or the allocation of numbers into species categories. Frequently, the net result of environmental stress is a redistribution of numbers among the various species. This may occur because sensitive or specialized forms undergo reduction or elimination while tolerant or generalized species increase in number. For this reason, integrative measures of community structure (i. e., species diversity indices) are useful in assessing environmental quality (Wilhm and Dorris, 1968; Swartz, 1972). However, because environmental quality is itself only defined relative to some arbitrary standard, such measures are informative only within a comparative framework.

In our study, comparison of species diversity indices (Shannon-Weaver, species richness, and evenness) derived from beach and vegetation collections can therefore quantitatively measure the quality of each habitat. Shannon-Weaver (information theory) diversity indicates the information content of each individual in a sample, and is a function of both the number of species (species richness) and the numerical distribution of species among the assemblage (species equitability) (Shannon and Weaver, 1963). Field studies have shown that Shannon-Weaver diversity applied to estuarine fish populations is inversely proportional to the amount of environmental or pollutional stress (Betchel and Copeland, 1971; Haedrich and Haedrich, 1974). Low information theory diversity is indicative of stressed or simple habitats, where the number of species is relatively low and a few species numerically dominate. Conversely, higher information theory values is characteristic of complex or unstressed habitats, where the number of species is high and the numerical distribution of species is more even. Determination of separate species richness and species evenness indices are also important, as the number of species depends primarily on the structural diversity of a habitat and evenness is more sensitive to the stability of physical conditions (Lloyd and Ghelardi, 1964).

Shannon-Weaver, species richness, and species evenness values are consistently higher for vegetated stations as compared to beach sites. Based on this, vegetated habitats are more complex and stable and less stressful than beach sites in Lake Conway. As a result, fish communities occupying vegetation are more complex and diverse in terms of number of species and number of individuals per species than fish populations in beach corridors.

Incidental observations during electroshocking reveal that a successional gradient in number of species collected is found among vegetated stations, unkept beaches where vegetation has encroached to some extent, and denuded beaches. This suggests that the beach fish community is a seral stage, whereas the vegetative associated ichthyofauna represents a terminal climax.

The piecemeal destruction of shallow emergent vegetation in lakes should be viewed with concern. We recommend that regulatory agencies, through public education and environmental laws, help preserve these vegetated shoreline habitats. We hope our paper will be of use in achieving this objective and in providing a stimulus to other workers to investigate the role of emergent vegetation in the aquatic ecosystem.

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Biological Sciences

WATERFOWL MANAGEMENT PRACTICES EMPLOYED IN FLORIDA AND THEIR EFFECTIVENESS ON NATIVE AND MIGRATORY WATERFOWL POPULATIONS

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Abstract: *In recent years, there has been a decline in Florida's waterfowl population, especially among the dabbling ducks and geese. There is much speculation as to what is responsible for this decline. Although Florida has an abundance of potential areas for waterfowl populations, very little intensive management is practiced on a statewide basis. I discuss the types of waterfowl management employed on Florida's wetlands and compare these practices with waterfowl populations occurring within the State. Problems confronting wetlands managers and some possible alternatives for management are discussed.*[*]

A superabundance of adequate wetlands allows Florida to be one of the leaders among southern states in terms of possessing potential waterfowl habitat. Florida wetlands include freshwater marshes, swamps, wet prairies, rivers, lakes, and brackish marshes. These areas represent some 27,680 km^2 in addition to a tidal coastline of approximately 5920 km (Chamberlain, 1960). Although Florida has available a vast amount of wetland habitat, much of it is of moderate or low quality for waterfowl management. Programs to develop these areas to their maximum potential are undertaken by the United States Department of the Interior (Fish and Wildlife Service), Florida Game and Fresh Water Fish Commission, and private landowners or conservation groups within the State. Even with the habitat shortcomings, Florida winters more waterfowl than any other state in the Atlantic Flyway (Chamberlain, 1960).

Florida Game and Fresh Water Fish Commission biologists and managers are working to keep the wetlands in the state as attractive as possible to waterfowl. Federal aid money, through the Pittman-Robertson Act, has contributed substantially to the State's investigations of ideal habitat, harvest, population figures, and currently to the study of water control programs that benefit waterfowl. Primarily, these projects are aimed at creating a greater hunter success n Florida, and secondly, they are concerned with sending the wintering waterfowl back to their northern breeding grounds in a healthy condition (Hutt, 1965).

National Wildlife Refuges are maintained in Florida and are probably more ntensively managed for wintering waterfowl than are most other similar areas within the State. The total acreage of National Wildlife Refuges in Florida is 170,882 ha as opposed to 645,861 ha which are under State control (Bellrose, 1976).

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[*] The costs of publication of this article were defrayed in part by the payment of charges from funds made vailable in support of the research which is the subject of this article. In accordance with 18 U.S.C. § 1734, this rticle must therefore be hereby marked "*advertisement*" solely to indicate this fact.

I evaluated all types of waterfowl management practices employed in Florida as to their effectiveness on both migratory and native waterfowl populations. Most of Florida's waterfowl population consists of winter migrants that come into the State via the Atlantic and Mississippi Flyways (Rodgers, 1974). Florida's nesting species include the Florida Duck (*Anas fulvigula fulvigula*), Wood Duck (*Aix sponsa*), Fulvous Whistling Duck (*Dendrocygna bicolor*), and some Blue-winged Teal (*Anas discors*) (Sprunt, 1954). Data were gathered on Florida's migrant and native waterfowl populations along with current management practices employed throughout the State at the federal, state, and private levels by questionnaires sent to biologists, ecologists, and refuge managers. Also, an extensive literature review was made of all available Florida waterfowl data. The relative importance and effectiveness of each management practice will be discussed, and then followed by recommendations for possible future programs.

Study Area—Fifteen of Florida's major waterfowl areas will be discussed (Fig. 1). Of the 27,680 km^2 of wetland habitat in Florida, approximately 17,600 km^2 are freshwater marsh, swamp, and wet prairie, while there are some 3,200 km^2 of saline marshes and waters (Chamberlain, 1960).

The coastal areas include inland brackish sounds, tidal creeks, salt marshes, and some freshwater impoundments. Typical submerged vegetation of these brackish areas is as follows: Widgeon grass (*Ruppia maritima*), muskgrass (*Chara* sp.), sago (*Potamogeton pectinatus*); emergent plants are black needle rush (*Juncus romerianus*), cordgrasses (*Spartina* spp.), and seashore saltgrass (*Distichlis spicata*). On some of the fresh water impoundments grow cattail (*Typha latifolia*), sawgrass (*Cladium jamaicensis*), smartweed (*Polygonum hydropiperoides*), waterlily (*Nymphaea odorata*), pickerelweed (*Pontederia cordata*), duck potato (*Sagittaria graminea*), cutgrass (*Leersia hexandra*), and American cupscale (*Sacciolepis striata*). The inland freshwater habitats are characterized by the foregoing vegetation as well as cypress trees (*Taxodium* spp.), primrose willow (*Ludwigia peruviana*), sea myrtle (*Baccharis halmifolia*), and buttonbush (*Cephalanthus occidentalis*). Many of the above plants are good waterfowl food sources.

Florida is divided into 5 topographic regions (Cooke, 1939): Western Highlands, Central Highlands, Coastal Lowlands, Marianna Highlands, and the Tallahassee Hills. Most of the State's prime waterfowl habitat is within the coastal lowlands. Florida's mean temperature is 22.32°C, while the average annual rainfall is approximately 120.62 cm (Reichelder, 1963). The mild winter climate is highly favored by migrating waterfowl.

Results and Discussion—Today's problems of waterfowl habitat management are those largely imposed by intensive land and water utilization. Availability of suitable habitat will always be an important limiting factor in waterfowl management.

The ecology of a marsh is a composite expression of the interplay of both chemical and physical factors. The soil type, its capacity to support plant growth; water chemistry; and turbidity—all influence the character of a wetland en-

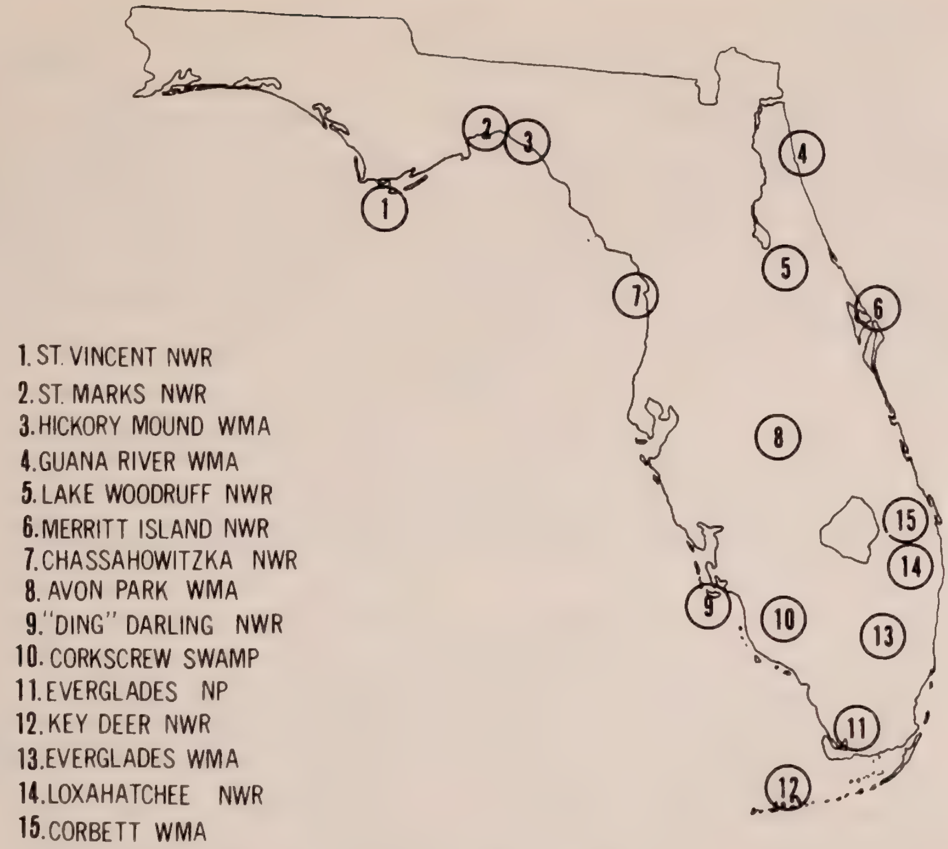

FIG. 1. Major waterfowl wintering areas in Florida that are managed or controlled to some legree. (NWR = National Wildlife Refuge; WMA = Wildlife Management Area; NP = National ark).

ironment and hence, in some degree, determine its value to waterfowl. The ollowing data were gathered from 15 waterfowl areas in Florida (Fig. 1):

rea	Managed Waterfowl Area (ha)	Est. Fall/Winter Pop. (1976-77)
1. Hickory Mound WMA (Taylor County)	365	5,000
2. Avon Park WMA (Polk Co.)	1,013	300
3. Everglades WMA (Dade/Broward/Palm Beach Cos.)	315,900	–
4. J. W. Corbett WMA (Palm Beach Co.)	22,680	–
5. "Ding" Darling NWR (Lee Co.)	700	8,000
6. Key Deer/Great White Heron NWR (Monroe Co.)	0	3,000
7. Lake Woodruff NWR (Volusia Co.)	5,022	6,000
8. Everglades National Park (Dade/Monroe Cos.)	0	26,000
9. St. Vincent NWR (Franklin Co.)	1,900	1,700
0. Loxahatchee NWR (Palm Beach Co.)	58,725	42,000

11. Merritt Island NWR (Brevard Co.)	30,780	90,000
12. St. Marks NWR (Wakulla/Jefferson/Taylor Cos.)	14,800	118,500
13. Corkscrew Swamp Sanctuary (Collier Co.)	0	500
14. Chassahowitzka NWR (Citrus Co.)	4,050	12,000
15. Guana River WMA (St. Johns Co.)	890	–

The management practices employed on the aforementioned areas are as follows:

1. Hickory Mound WMA—Controlled burning and water and salinity level fluctuation.
2. Avon Park WMA—Controlled burning; water level fluctuation, chemical weed control and chopping/disking.
3. Everglades WMA—Controlled burning and water management recommendations to Southern and Central Flood Control District.
4. J. W. Corbett WMA—Controlled burning and water management.
5. "Ding" Darling NWR—Impoundment construction; aquatic weed control and proposed flood gate installation.
6. Key Deer/Great White Heron NWR—Protection only.
7. Lake Woodruff NWR—Controlled burning; aquatic weed control; water level fluctuation and wood duck nest box installation.
8. Everglades National Park—Protection only.
9. St. Vincent NWR—Controlled burning and water level fluctuation.
10. Loxahatchee NWR—Water level fluctuation.
11. Merritt Island NWR—Water level fluctuation in coordination with mosquito contro project and controlled burning.
12. St. Marks NWR—Water and salinity level fluctuation; controlled burning; food plots; protection and disking.
13. Corkscrew Swamp Sanctuary—Some ducks utilize area devoted to food productio for wood storks (*Mycteria americana*).
14. Chassahowitzka NWR—Protection and management as natural area.
15. Guana River WMA—Controlled burning and water level fluctuation.

The most common wintering waterfowl species on the inland and coastal areas discussed within this report are as follows (most common listed first, least common liste last): *Inland Areas* (Fig. 1) (Everglades WMA, Corbett WMA, Avon Park WMA, Lak Woodruff NWR, Loxahatchee NWR, and Corkscrew Swamp Sanctuary): Ring-necke duck (*Aythya collaris*), Blue-winged Teal, Green-winged Teal (*Anas crecca*), America Widgeon (*Anas americana*), Wood Duck, Pintail (*Anas acuta*), Shoveler (*Anas clypeata* Gadwall (*Anas strepera*), Lesser Scaup (*Aythya affinis*), Fulvous Whistling Duck, an Black Duck (*Anas rubripes*). *Coastal Areas* (Everglades NP, "Ding" Darling NW Merritt Island NWR, St. Marks NWR, St. Vincent NWR, Hickory Mound WMA, Chassahowitzka NWR, and Key Deer NWR): Lesser Scaup, Pintail, Blue-winged Teal, Red breasted Merganser (*Mergus serrator*), American Widgeon, Shoveler, Green-winged Tea Ring-necked Duck, Redhead (*Aythya americana*), Canvasback (*Aythya valisineria* Mallard (*Anas platyrhynchos*), Gadwall and Black Duck.

The skillful manipulation of habitat and the growing of supplemental food can be intensified by proper use of land and water. To develop a better understanding of the many ramifications of water level management, gauge record should be maintained and ecological surveys made annually to provide con parative data showing changes in plant succession, food production, and waterfowl utilization.

Fluctuation of water levels can be the best management tool a refuge manager employs if done at proper intervals. For management of emergent vegetation, the drawdown practice of water level control is used in areas where waters are acid, turbid, and soils of low quality. These drawdowns retard the growth of undesirable plants and encourage the growth of good waterfowl food plants. They also serve to flush out the impoundments and help to eliminate pollution and decaying matter (Reed, 1976). Perennial and annual food plants may be managed by drawdown dependent upon the species being managed. Drawdowns should be as late as possible in the season, yet still early enough to allow seed propagation for fast growing aquatic plants like cutgrass and annual smartweeds which may become established on moist mud flats (Giles, 1971). Periodic drawdowns can contribute to much algal growth following reflooding (Griffith, 1957). This occurred on the Hickory Mound Wildlife Management Area in 1970 (Lazor and McDaniel, 1973). In conjunction with these drawdowns, it should be noted that agricultural crops such as corn (*Zea mays*), browntop millet (*Panicum ramosum*), Japanese millet (*Echinochloa crusgalli*), and chufa (*Cyperus esculentus*) can be planted and then reflooded prior to the arrival of ducks in the fall. Al-hough this is usually an expensive practice, it can result in high numbers of wintering waterfowl. Ducks will come to almost any area covered with water, but they seldom stay unless they find an ample supply of food. Duck fields are very common in the northern areas around Tallahassee, where large private plantations are maintained. Duck fields are areas which are kept dry to produce ield crops and then flooded during the fall and winter to make the crops available to ducks. Although expensive, a good duck field planted in corn and millet often produces more food than does a pond or marsh. These fields must have likes surrounding them and a water control mechanism that will allow proper looding in the fall and winter. After the crop is mature, it must be left standing nd then flooded. It is illegal to attract ducks for hunting by mowing or breaking lown the corn or by shelling and shucking it.

Excellent waterfowl areas can be, and are, maintained in coastal areas. These ites are not normally suited for planting crops. Salt marshes generally have a eavy growth of needlerush or cordgrass, both which are almost worthless as uck foods (Neely and Davidson, 1966). They can be replaced with widgeongrass r saltmarsh bulrush, depending on the salinity of the area. Water level control is the most common technique used in Florida for maintaining successful bulrush ponds.

Controlled burning is useful in managing marshes for ducks and geese. Like razing, burning can be used to reduce coarse, perennial marsh plants and create avorable conditions for growing natural duck foods. Dead stems and other litter f previous years' growth gradually fill a marsh. This debris eliminates open water and makes feeding difficult or impossible. Burning every second year will reduce this problem.

These basic management techniques are not as intensively practiced in Florida as they could be. Over the past few years, there has been a gradual decrease in Florida's waterfowl population, especially among the dabblers and geese (Fogarty, 1970). Inadequate wetlands management, shortstopping in states further north, and high density airboat traffic in certain areas may all contribute to the problem. Expansions should be made to develop waterfowl areas through the overall use of supplemental food plantings, controlled burning, water level fluctuations, and protections where necessary.

Florida annually winters 17-26% of the Atlantic Flyway duck population (Chamberlain, 1960). When compared to other Atlantic Flyway states, the average hunter kill for Florida duck hunters is generally higher for such species as American Widgeon, Ring-necked Duck, Green-winged Teal, Blue-winged Teal, Shoveler, Pintail, Lesser Scaup, and Ruddy Duck (*Oxyura jamaicensis*), (Geis and Cooch, 1972). Improvement of water and food conditions does not always result in an automatic increase in waterfowl populations. This is because flyway population fluctuations and other phenomenon such as weather, food conditions, and water levels in other wintering areas may alter a bird's migration patterns. Despite the vast amount of available habitat, most of Florida's wintering waterfowl populations occur on only 4% of the total area within the State (Chamberlain, 1960).

SUMMARY—Specific management techniques to improve waterfowl habitat on any area must be individually designed and executed because no 2 areas are exactly alike ecologically (Sincock and Powell, 1957). Care must be taken to prevent excesses in management which might shortstop waterfowl in migration or practices that prevent a reasonable harvest of ducks and geese. Herein lies a delicate balance seldom achieved and never long maintained. The forces of nature and humanity shift continually. In areas of low quality habitat and heavy gun pressure, waterfowl quickly seek out managed marshes and resting areas beyond the reach of the hunter. In these instances, lowering the quality of management benefits neither waterfowl nor sportsman.

There are 2 groups of conservationists mainly concerned with the enjoyment and use of the waterfowl resource: the duck hunters and those concerned with aesthetic values. The latter group is much the larger. The interest and support of the aesthetically minded should be considered in the national refuge program. Opening an entire refuge to hunting would be a disservice to these dedicated conservationists. On the other hand, a well managed closed area serves the interests of both the duck hunter and the nature lover. Studies conducted by Bellrose (1953) showed a consistently higher waterfowl kill on hunting grounds adjoining a closed area. A closed area properly located may permit waterfowl to use feeding grounds within a radius of 20-30 km and hunters in the vicinity benefit from the daily feeding flights of the waterfowl. Public hunting is allowed on 6 of the 15 areas mentioned in this study; hunter success was graded moderate to good on these areas.

A judgment of Florida's waterfowl management programs would be one of classifying the overall program as satisfactory, but needing improvements in certain areas. There could be many expansions made in management schemes throughout the State which would probably benefit wintering and native waterfowl. Until the problem of shortstopping can be at least partially solved, Florida's prognosis is still dim as far as increasing populations of dabbling ducks and geese.

In the final analysis, it is the public which has created much of the annual waterfowl crisis. People have been indifferent to subsidized drainage, to winter and summer habitat destruction, to overshooting, and to insufficient law enforcement. The decisions made over the next decade concerning waterfowl will determine whether the duck will remain a game bird or become a museum piece in Florida as well as in the rest of North America.

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Biological Sciences

STATUS OF TWO ENDANGERED FLORIDA SPECIES OF CHAMAESYCE (EUPHORBIACEAE)

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ABSTRACT: Chamaesyce deltoidea, *with its infraspecific taxa, and* Chamaesyce pinetorum *were studied with regard to morphology, distribution, habitat, and taxonomy. Analysis of the data supports the ranking of the taxa as discussed by Burch (1966). In addition, the endangered status of the taxa is discussed, and a recommendation is made for the addition of* C. pinetorum *to the endangered list. Thirty-two specimens were examined; 15 for* C. deltoidea *and 17 for* C. pinetorum.*

CHAMAESYCE, usually considered a weedy pest, is represented in southern Florida by several endemic species. One of these endemics, *C. deltoidea*, which is on the Endangered Species List (Smithsonian, 1975), has been divided into infraspecific taxa. The last investigation of these plants was made by Burch (1966) over a decade ago and involved mostly herbarium specimens. My study began as a field evaluation of the population status of *C. deltoidea* and a check of the taxa within that species and the allied species *C. pinetorum*. Thirty-two specimens were examined; 15 of *C. pinetorum* and 17 of *C. deltoidea*.

MORPHOLOGY—All specimens were examined and characters recorded using accepted terminology (Lawrence, 1951). Morphological measurements were standardized. Five leaves were selected on each plant: the largest, the smallest, and three at random. Length from petiole to apex was recorded for each. The width of each was taken as the maximum dimension perpendicular to the length axis. Capsules, all available, were treated similarly. The length from capellate flower to pedicel was recorded and the maximum dimension perpendicular to the length axis taken as the width. In addition, slides were made of trichomes from leaf and stem surfaces and their morphology and dimensions were recorded.

Numerical analysis of the continuous characters (Table 1) as well as scatter diagram analysis showed little distinctness between the groups. This indistinctness was due primarily to the large variation in the ranges for each character in and between groups (Table 1). The groups show morphological distinctness only with regard to discontinuous characters, and an ideogram exhibits these differences (Fig. 1). To better quantify these differences, characters were scored (Table 2) and a similarity matrix was constructed (Fig. 2). The phenogram (Fig. 2) derived from this matrix was used to support the ranking of the taxa based on their degree of similarity in characteristics.

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*The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U. S. C. § 1734 this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

TABLE 1. Continuous character averages and ratios for 4 taxa of *Chamaesyce.*[1]

Character	Taxon 1	Taxon 2	Taxon 3	Taxon 4
Leaf length	2.7 (2.5-2.7)[2]	3.2 (2.5-3.0)[2]	2.7 (2.0-3.5)[2]	3.3 (2.5-4.1)[2]
Leaf length/width	1.1 (1.1-1.2)	1.2 (1.1-1.3)	1.2 (0.8-1.6)	1.0 (0.8-1.2)
Cyathium length/width	1.2 (1.1-1.3)	1.1 (0.8-1.3)	1.0 (0.6-1.5)	1.2 (0.7-1.4)
Capsule length/width	1.2 (0.9-1.0)	1.0 (0.8-1.2)	1.0 (0.8-1.5)	0.9 (0.7-1.0)
Peduncle length	1.0 (0.9-1.1)	1.7 (1.3-2.5)	1.0 (0.0-2.5)	1.5 (0.8-2.0)
Seed length	2.0 (1.9-2.1)	1.2 (0.7-1.7)	1.9 (1.7-2.5)	1.9 (1.4-2.0)

[1] Key to taxa: 1—*C. deltoidea deltoidea* var. *deltoidea*; 2—*C. deltoidea deltoidea* var. *adhaerens*; 3—*C. deltoidea serpyllum*; 4—*C. pinetorum*.

[2] Mean and range in mm.

TABLE 2. Scores by operational taxonomic units of 4 taxa of *Chamaesyce.*[1]

Character	A	B	C	D
Leaf upper surface	1	2	4	3
Leaf lower surface	2	2	4	3
Stem pubescence	1	1	4	2
Capsule pubescence	1	2	3	2
Cyathium pubescence	1	1	3	2
Capsule length/width	1	2	2	1
Trichome length/width	1	1	1	2
Habit of plant	1	1	1	2
Pedicel pubescence	1	1	3	2

[1] Key to taxa: A—*C. deltoidea deltoidea* var. *deltoidea*; B—*C. deltoidea deltoidea* var. *adhaerens*; C—*C. deltoidea serpyllum*; D—*C. pinetorum*. Scoring code: For leaf upper and lower surface, 1-glabrous 2-sparsely pilose 3-pilose 4-tomentose; For stem, capsule, pedicel, and cyathium vestiture, 1-glabrous 2-pilose 3-tomentose; For capsule length/width, 1-less than 1.0 2-greater than 1.0; For trichome length/width, 1-5 2-20; For plant habit, 1-decumbent 2-erect.

DISTRIBUTION—The distribution of the groups is allopatric and non-contiguous except for the 2 varieties of subspecies *deltoidea* which appear to be sympatric populations (Fig. 3). Each of the populations appears to be restricted to a small geographic area. *Chamaesyce pinetorum*, for example, was found essentially restricted to Long Pine Key in the Everglades National Park. However, specimens of *C. pinetorum* collected by R. W. Long were found in Peter's Prairie west of Homestead. An additional population has been reported near the Fire Tower on U.S. 27 (G. Avery, pers. comm.). *Chamaesyce deltoidea serpyllum* is more restricted, having been reported only on the north and south ends of Big Pine Key. The 2 varieties of *Chamaesyce deltoidea deltoidea* have only been found in the Old Cutler Road/Black Creek area of Coral Gables.

HABITAT—All specimens were collected in similar sites. Their habitat may be characterized as disturbed, xeric pinelands with exposed limestone or oolite. The plants usually form mats on the exposed rock; rootstocks and stem bases emerge from pits or cracks in the rock. *Chamaesyce pinetorum* differs in appearing either erect or ascending through overlying pine needles. These plants were not found in areas adjacent to collection sites where the pineland areas were either wetter or the rock had been covered by soil or sand.

Discussion—The morphological and geographical data presented in this study supports the ranking of the populations as 2 species, *Chamaesyce pinetorum* and *C. deltoidea*. *Chamaesyce deltoidea* has 2 subpopulations, subspecies *serpyllum* (OTU, operational taxonomic unit 3) and subspecies *deltoidea* (OTU 1 and 2). Subspecies *deltoidea* may be further divided and these populations are considered varieties.

Chamaesyce pinetorum and *C. deltoidea* are given species rank on the basis of their low degree of similarity in characteristics (11%) as compared to the subgroups of *deltoidea* which show a 33% similarity. In addition, each species is distinct morphologically with regard to plant habit, pubescence of various structures, and trichome type (Figs. 1 and 2). Further support for this ranking comes from their allopatric, non-contiguous distribution. *Chamaesyce pinetorum* occurs inland on the Everglades Keys; the other groups are coastal.

The subpopulations *deltoidea* (OTU 1 and 2) and *serpyllum* (OTU 3) of species *deltoidea* are considered subspecies because their distributions are allopatric and non-contiguous (Fig. 3) and their morphological similarity is greater (33%) than at the species level. This similarity is seen particularly with respect to habit and trichome morphology. The disjunct distribution may be due to habitat selec-

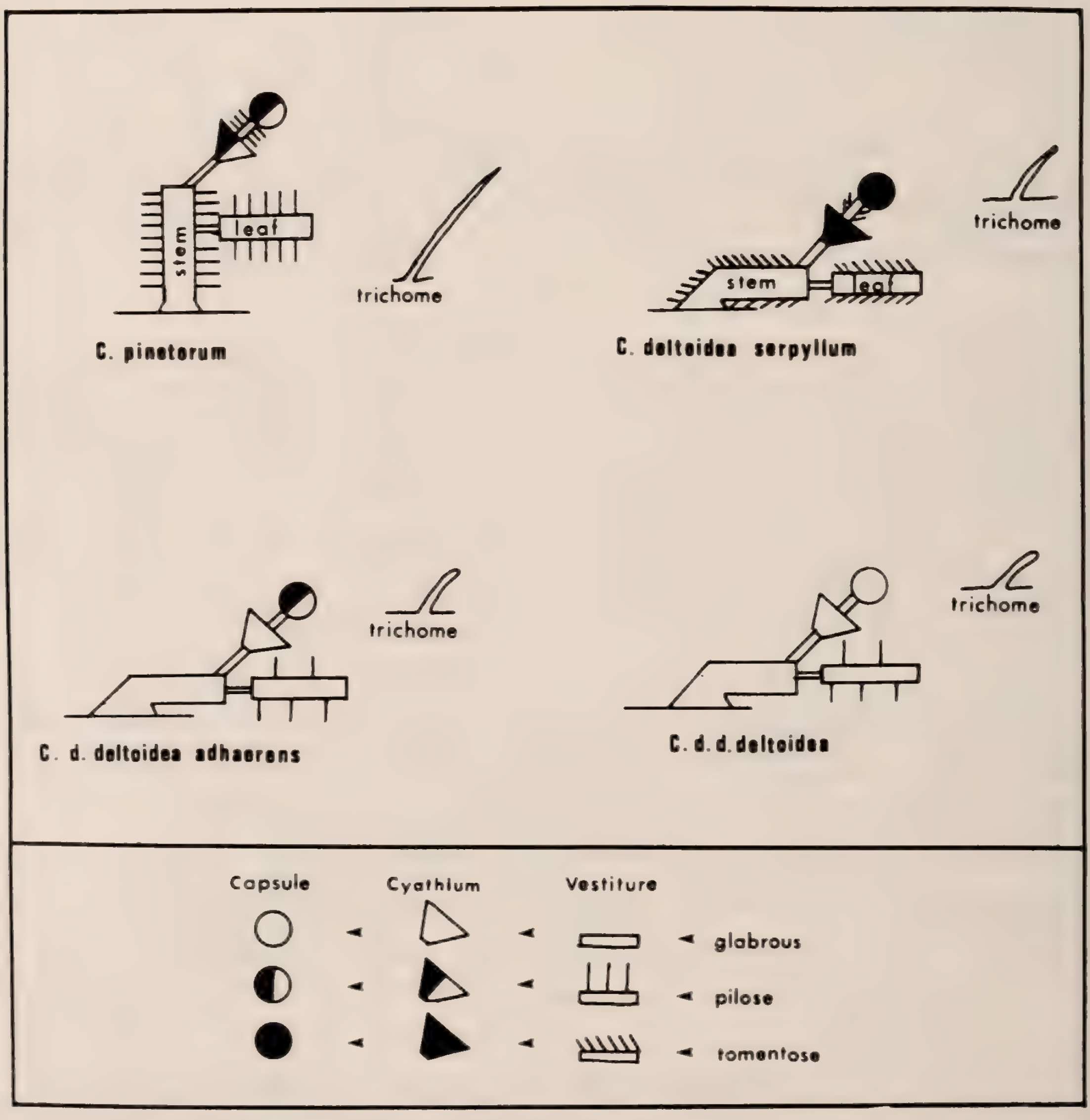
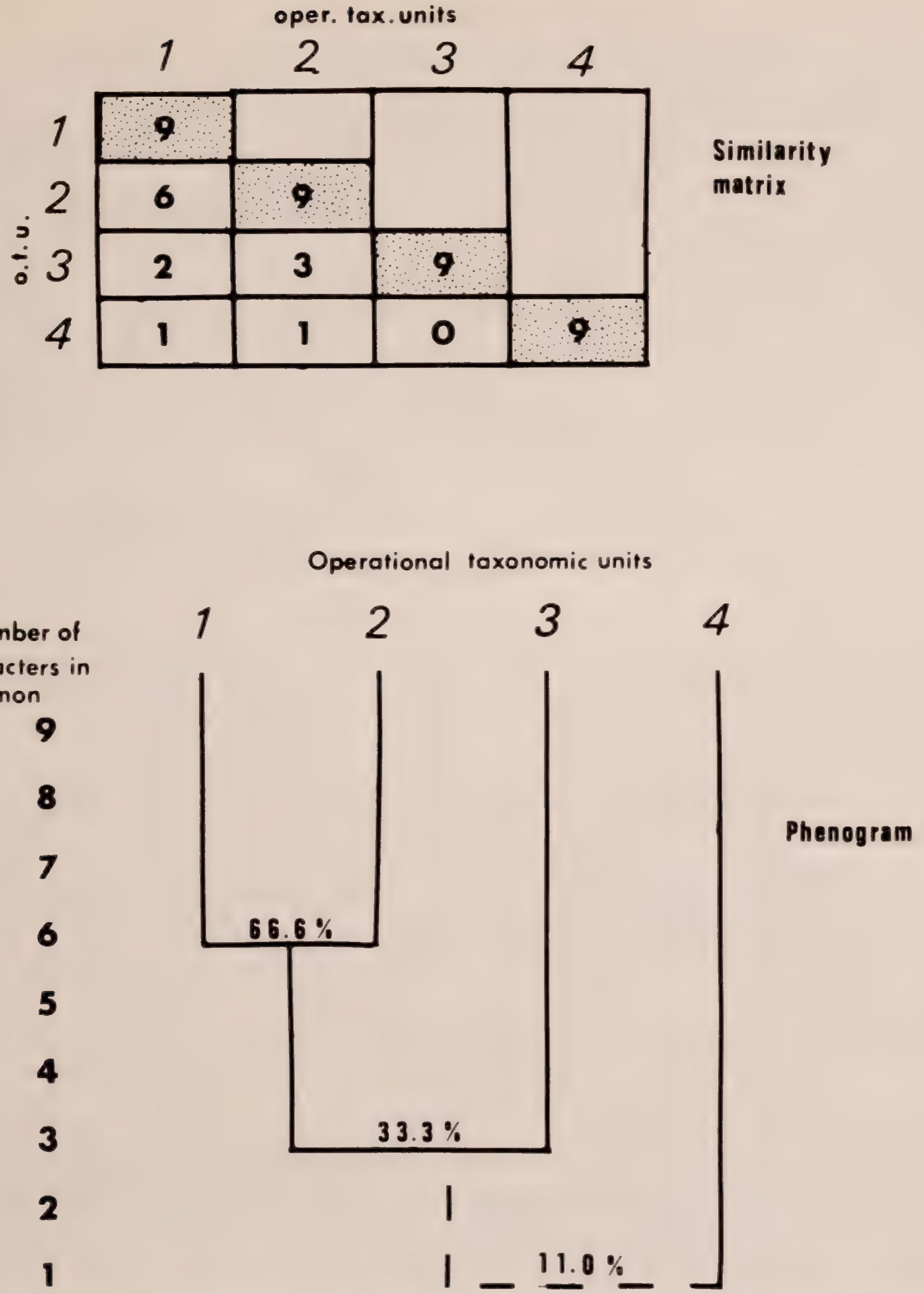


Fig. 1. Comparative ideograms of 4 taxa of *Chamaesyce*.



o.t.u.	1	2	3	4
1	9			
2	6	9		
3	2	3	9	
4	1	1	0	9

FIG. 2. Similarity matrix and phenogram for 4 taxa of *Chamaesyce*. Characters and scores derived from Table 2.

tion (Big Pine Key being one of the few Keys with xeric pinelands) and isolation of the extremes of a wider distribution by a geological or ecological barrier with subsequent divergent evolution.

Subpopulations of subspecies *deltoidea* (OTU 1 and 2), *deltoidea* and *adhaerens* are considered varieties on the basis of their sympatric distributions and their high degree of morphological similarity (66%). This similarity is so marked that sterile specimens are difficult to differentiate. The distinctive characters are pubescence of capsule and leaf.

Herbarium specimens examined represent populations as they existed 10-40 yr ago; they are not representative of currently existing populations. Probably

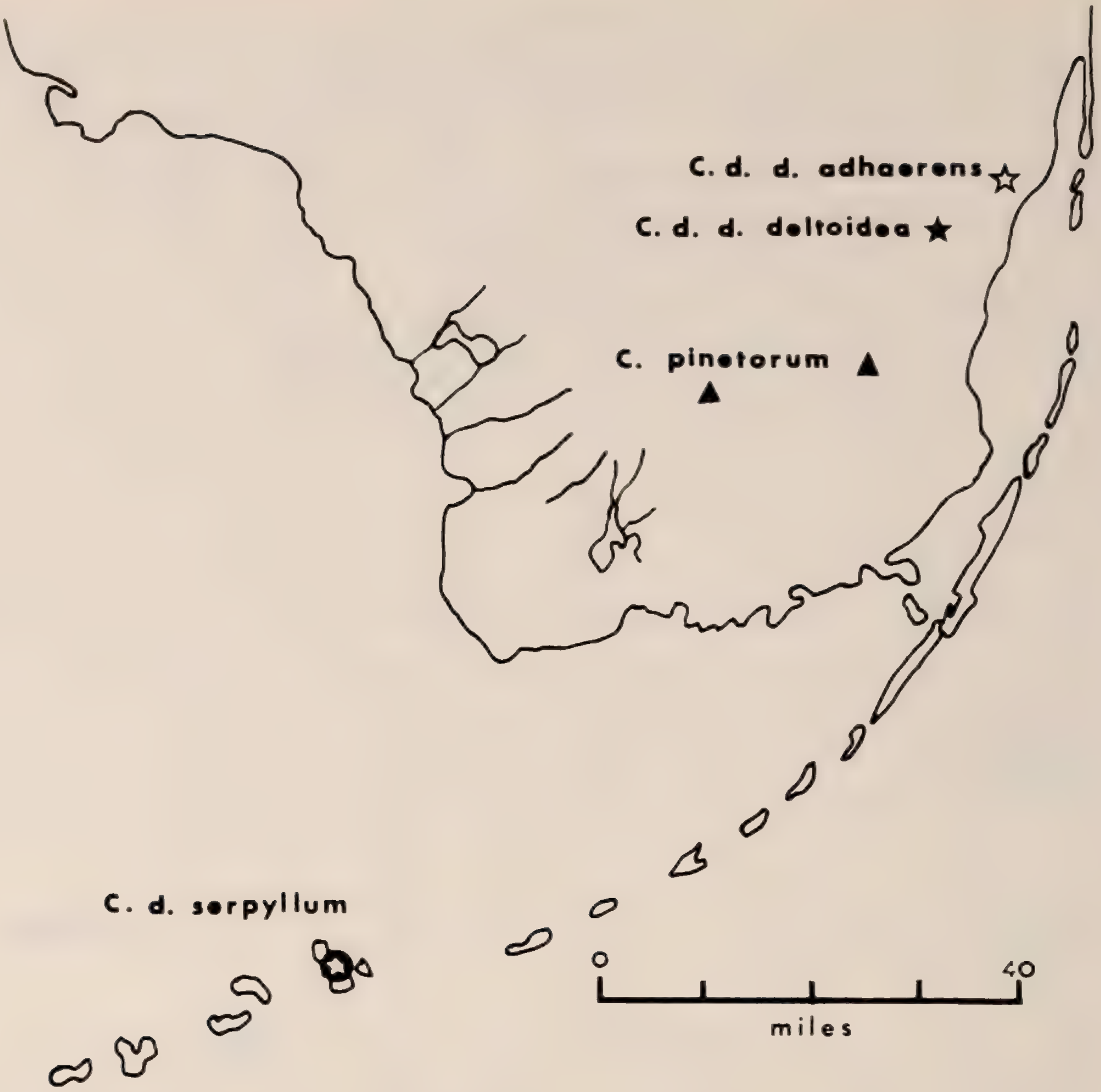


Fig. 3. Distribution of 2 species of *Chamaesyce* in South Florida.

the several herbarium specimens of rare taxa suggest larger populations than now exist. Field observations carried out in this study suggest that the gene pools may be so reduced that *Chamaesyce deltoidea* and *C. pinetorum* are both approaching extinction. Therefore, it is recommended that both *C. deltoidea*, with its infraspecific taxa, and *C. pinetorum* be considered as endangered species.

Acknowledgments—Thanks are extended to Dan F. Austin of Florida Atlantic University for his many helpful suggestions.

ARTIFICIAL KEY

1. Stem pubescent (tomentose or pilose) 2
1. Stem glabrous 3
2. Stem, leaves, capsule, and pedicel tomentose; plant decumbent .... *C. deltoidea serpyllum.*
2. Stem, leaves, capsule, cyathium, and pedicel pilose; plant erect or ascending .... *C. pinetorum.*
3. Capsule glabrous; leaves sparsely pilose above and below .... *C. deltoidea deltoidea* var. *deltoidea.*
3. Capsule pilose at lateral edges; leaves sometimes sparsely pilose above and below .... *C. deltoidea deltoidea* var. *adhaerens.*

TAXONOMY

1. *Chamaesyce deltoidea* (Engleman ex Chapman) Small, Flora Southeastern U.S. p. 710, 1903. subsp. *deltoidea* var. *deltoidea* Basionym: *Euphorbia deltoidea* Engleman ex Chapman, Flora Southeastern. U.S. Suppl. p. 647, 1883. South Florida.

Small, monoecious, prostrate to decumbent herb occurring in mats over exposed limestone. Stems terete, brown, dia 0.3-0.6 mm, glabrous. Leaves deltoid, 2.0-2.5 mm long, 2.0-3.0 mm wide, glabrous above to sparsely pilose below, apex obtuse, base cordate, margins entire; stipules laciniate, brown to reddish brown with light tips, glabrous. Inflorescence solitary, terminal, shortly pedunculate (1 mm long); cyathium 1.2 mm long, 1.0 mm wide, glabrous; glands 4, green, ovate, appendages minute. Capsule fully exserted at maturity, 1.0 mm long, 1.0 mm wide, glabrous all over; pedicel glabrous. Seeds 3, 1.0 mm long, 0.5 mm wide, ovate, glabrous, 4 ridged laterally, yellowish white. Flowering season late summer to early fall. Disturbed, xeric pinelands over exposed limestone (oolite); Coral Gables, Dade Co., Florida. Endemic.

Specimens Examined—Old Cutler Road, Coral Gables, Popenoe, Craighead, and Lakela 2726 (USF); Craighead s.n. (FTG); S.W. 112 St. and Colonial Dr., Perrine, Popenoe 865 (FTG).

2. *Chamaesyce deltoidea* (Engleman ex Chapman) Small subsp. *deltoidea* var. *adhaerens* (Small) Burch. Ann. Missouri Bot. Gard. 53:98. 1966. Based on *C. adhaerens* Small. Torreya 27:104 1927. Type: Pinelands between Peter's Prairie and Homestead, Florida. 1906. Small and Carter 2531 (holotype N.Y. n.v.).

Small monoecious, prostrate to decumbent herb in dense mats. Stems terete, brown, dia 0.3-0.6 mm, glabrous. Leaves deltoid, 2.0-3.0 mm long, 2-3 mm wide, glabrous to sparsely pilose above and below, apex obtuse, base cordate, margins entire; stipules laciniate, brownish red with white tips. Inflorescence solitary, terminal, pedunculate (1.5 mm long); cyathium 1.1-1.5 mm long, 1.0-1.5 mm wide, glabrous proximally to pilose distally; glands 4, green, ovate, appendages minute. Capsule fully exserted at maturity, 1.0-1.5 mm long, 1.0-1.5 mm wide, glabrous except pilose at lateral edges, pedicel glabrous. Seeds 3, 1.0 mm long, 0.5 mm wide, ovate, glabrous, 4 ridged laterally, yellowish orange to reddish orange. Flowering season Aug-Sept. Disturbed, xeric pinelands over exposed limestone (oolite). Old Cutler Road/Black Creek area, Dade Co., Florida. Endemic.

Specimens Examined—Dade Co., Craighead s.n. (FTG); Coral Gables over oolite, Lakela and Pardue 31583 (USF); Old Cutler Rd., Coral Gables, Lakela and Almeda 30450 (USF); Old Cutler Rd. opposite Montgomery Foundation, Craighead s.n. (FTG); Old Cutler Rd., south of Cutler Hammock, Correll 40666 (FTG).

3. *Chamaesyce deltoidea* (Engleman ex Chapman) Small subsp. *serpyllum* (Small) Burch. Ann. Missouri Bot. Gard. 53:99, 1966. Based on *Chamaesyce serpyllum* Small. Fl. Florida Keys. 81, 1913. Type: Big Pine Key, Monroe Co., Florida. 1912 Small 3811 (holotype N.Y. n.v.).

Small monoecious, prostrate to decumbent herb occurring in diffuse mats. Stems terete, brown, dia 0.3-0.6 mm, tomentose, nodes woolly. Leaves deltoid, 2-4 mm long, 2-4 mm wide, tomentose above and below, apex obtuse, base cordate, margins entire; stipules laciniate, brown to white with tips sometimes white. Inflorescence solitary, terminal with infrequent subterminal, shortly pedunculate (up to 1 mm long); cyathium 1-2 mm long, 1.5-2.0 mm wide, glabrous proximally to tomentose distally; glands 4, green, ovate, appendages minute. Capsule fully exserted at maturity, 1.1-1.5 mm long, 1.5-2.0 mm wide, tomentose at lateral edges, pedicel glabrous to tomentose. Seeds 3, 1 mm long, 0.5 mm wide, ovate, glabrous, 4 ridged laterally, yellowish orange to reddish orange. Flowering season Jun-Dec. Disturbed, xeric pinelands over limestone (oolite). N and S ends of Big Pine Key, Monroe Co., Florida. Endemic.

Specimens Examined—Big Pine Key, Buswell s.n. (USF); N end of Big Pine Key over limestone, Poppleton and Shuey s.n. (USF); Watson's Hammock Trail, Big Pine Key, Long 2127A (USF); Remus C-002 (FAU); Remus C-003 (FAU); Pineland, N Big Pine Key, Lakela and Craighead 29293 (USF).

4. *Chamaesyce pinetorum* Small, Bull. N.Y. Bot. Gard. 3:429, 1905. Florida. Dade Co., Between Cutler and Longview Camp, in pinelands near the Homestead road. 9-12 Nov 1903. Small and Carter 836 (holotype N.Y. n.v.).

Small monoecious, ascending to erect herb. Stems terete, brown, dia 0.3-0.6 mm, pilose, nodes and sterile termini woolly. Leaves deltoid, 2-4 mm long, 2-5 mm wide, pilose above and below, apex obtuse, base cordate, margins entire; stipules laciniate, tan to brownish red with white or darker tips. Inflorescence solitary, terminal, pedunculate (1-2 mm long); cyathium 1.5 mm long, 1.0 mm wide, pilose all over; glands 4, green, ovate, appendanges minute. Capsule fully exserted at maturity, 1.5 mm long, 1.0 mm wide, pilose, pedicel pilose. Seeds 3, 1 mm long, 0.5 mm wide, glabrous, 4 ridged laterally, reddish orange to red. Flowering season late fall to early winter. Disturbed, xeric pinelands over limestone (oolite). Western Dade Co., Florida. Endemic.

Specimens Examined—Aerojet road, south of Florida City in gladelands, Long 1653 (USF); Pineland near Homestead off U.S. 27, Long 1725 (USF); Near Homestead in Everglades National Park, pinelands, Cooley, Craighead and Eaton 9411 (USF); In Redlands near corner of Krome Ave and Bauer Dr., pinelands, Popenoe 658 (FTG); Long Pine Key Campground, Everglades National Park, Austin 6650 (FAU), Austin 6659 (FAU), Remus C-007 (FAU).

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Biological Sciences

SOME BENTHIC MARINE ALGAE NEW TO PUERTO RICO

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Abstract: *Fifty-five species of marine algae are newly reported from Puerto Rico. This number brings to about 360, the total algal flora known for Puerto Rico.*°

Marine benthic algae from Puerto Rico have been studied by various investigators over the past 80 yr. Ecological studies such as those of Hauck (1888), Howe (1903, 1915), Britton (1906), and Foslie and Howe (1906) dealt primarily with collections gathered at random around the coast. Subsequently, systematic collections made by Almodóvar and Blomquist (1959, 1961, 1965), Almodóvar

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[1] The late Dr. Hugo Blomquist spent the years 1940, 1941, and 1948 studying cryptogamic plants in Puerto Rico. During that time, he collaborated with the senior author on a catalogue of Puerto Rican algae, a work that was never published. The inclusion of Dr. Blomquist's name recognizes his contribution to the present knowledge of the Puerto Rican marine algal flora.

°The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U. S. C. § 1734 this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

(1962, 1964a, b, 1970), Díaz (1963, 1965, 1970), and Ballantine (1977) have provided further information on the flora.

Since 1970, the continued research of the authors, students in the Dept. of Marine Sciences (Univ. of Puerto Rico), and visiting scientists has lead to further records of algae previously unknown from the island. As the algal flora of Puerto Rico has been one of the most closely studied in the West Indies, and these records provide additional knowledge of the distribution of marine plants in the Caribbean, we feel it appropriate to publish these additions. This report brings to about 360, the total number of algal species, excluding blue-green algae, presently known for Puerto Rico.

Specimens have been deposited in one or more herbaria. Abbreviations used to designate location conform to those proposed by Lanjouw and Stafleu (1964). Exceptions (not found in the index) are as follows: COL, Columbia University, Lamont Observatory; IMB, Herbarium, Dept. of Marine Sciences, Univ. of Puerto Rico; IIP, Herbarium, Investigaciones Pesqueras, Barcelona, Spain.

LIST OF TAXA

Chlorophyta

CHAETOPHORACEAE

Phaeophila dendroides (Crouan) Batters. La Parguera: 55′, D.L.B., 2 Mar 1976; 28 Apr 1976 (IMB).

Entocladia viridis Reinke. La Parguera: 55′, endophytic, D.L.B., 29 Aug 1973; 12 Nov 1973 (IMB).

CHAETOPELTIDACEAE

Diplochaete solitaria Collins. La Parguera 55′, epiphytic, D.L.B., 22 Dec 1975; 2 Mar 1976; 28 Apr 1976 (IMB).

GOMONTIACEAE

Gomontia polyrhiza (Lagerheim) Bornet & Flahault. La Parguera: dead corals, Cueva Island, H.L.B. & L.R.A. 3278, 24 Apr 1958 (IMB).

CLADOPHORACEAE

Chaetomorpha aerea (Dillwyn) Kützing. Arecibo: 25′, Islote, D.L.B., 12 Oct 1974 (IMB). Patillas: H.L.B. 12161, 9 Nov 1941 (DUKE); gravel beach, L.R.A. and V.M. Rosado 4218, 13 Aug 1961 (COL, D, DUKE, IMB, L, NY, UC, US); L.R.A. & V.M. Rosado 4669, 6 Nov 1962 (DUKE, IMB, L, NY). San Juan: Condado, H.L.B. 11972, 6 Oct 1941 (DUKE); H.L.B. 12115, 31 Oct 1941 (DUKE, IMB).

Chaetomorpha crassa (C. Agardh) Kützing. Culebra: on rocks, Dewey, L.R.A. & V.M. Rosado 3999, 25 Mar 1961 (COL, D, DUKE, IMB, L, NY, UC, US).

Rhizoclonium hookeri Kützing. Guajataca: entangled among other algae, H.L.B. 12041, 18 Nov 1941 (DUKE). Yabucoa: on rocks, A.E. Rehm 6896, July 1973 (IMB, NY).

Rhizoclonium kerneri Stockmayer. Guánica: on wood at low tide mark, Ballena Bay, M.A. Howe 6944b, 20 June 1915 (IMB). Mayaguez: shallow water, Punta Arenas, H.L.B. 10 June 1958 (IMB). La Parguera: epiphytic, 55′, Media Luna, D.L.B. 29 Aug 1973; 19 Feb 1974; 28 Apr 1976 (IMB).

Cladophora catenata (C. Agardh) Ardissone. Aguirre: on rocks near shore, Phillips breakwater, L.R.A. & V.M. Rosado 6202, 10 Mar 1970 (ADE, D, DUKE, IMB, L, NY, UC, US). Fajardo: on rocks, shallow water, H.L.B. 12833, 7 Mar 1942 (DUKE, IMB). Guataca: canal, at low tide mark, (H.L.B. & L.R.A. 3202, 16 Apr 1958 (ADE, D, DUKE, IMB, IU, L, NY); tide pools, L.R.A. & V.M. Rosado 4858, 18 Sept 1963 (D, DUKE, IMB, L, NY, UC, US). Loiza: Medianía Alta, A. & E. Ortiz 6675, 24 July 1971 (IMB, NY). Luquillo: Costa Azul, A. & E. Ortiz 6690, 24 July 1971 (IMB, L, NY, UC, US). Yabucoa: on rocks, EL Negro, L.R.A. and V.M. Rosado 4972, 22 Jan 1964 (ADE, D, IIP, IMB, L, NY, UC, US).

Cladophora crispula Vickers. Luquillo: on rocks, Luquillo Beach, H.L.B. 12328, 16 Dec 1941 (DUKE). Patillas: gravel beach, H.L.B. 12880, 14 Mar 1942 (DUKE); L.R.A. and V.M. Rosado 4935, 16 Jan 1964 (ADE, D, IIP, IMB, L, NY, UC, US).

Cladophora pulverulenta (Mertius) Phinney. Guanica: shallow water among other algae, H.L.B. 13023, 31 Mar 1952 (IMB).

Valoniaceae

Struvea anastomosans (Harvey) Piccone. Cabo Rojo: on rocks, Playa Sucia, H.L.B. & L.R.A. 3088, 3 Mar 1958 (IMB); on mangrove roots, Punta Ostiones, L.R.A. & V.M. Rosado 4543, 14 May 1962 (IMB). Culebra: breakwater, Flamingo Beach, L.R.A. & V.M. Rosado 4066, 26 Mar 1961 (IMB). Guanica: on rocks, Las Pardas, L.R.A. & V.M. Rosado 5056, 5 Feb 1964 (IMB). Guayanilla: Cayo María Langa, L.R.A. et al. 6125, 26 Feb 1970 (DUKE, IMB, NY). La Parguera: on mangrove roots, D.L.B. 16 Jan 1975 (IMB); epiphytic, Margarita Reef, 80′, D.L.B. 12 Nov 1973 (IMB).

Struvea ramosa Dickie. Santurce Beach, H.L.B. 12514, 30 Jan 1942 (DUKE).

Derbesiaceae

Derbesia vaucheriaeformis (Harvey) J. Agardh. La Parguera: on mangrove roots, Gata Is., L.R.A. 3115, 10 Mar 1958 (IMB); Cueva Is., L.R.A. 7182, 28 Feb. 1975 (IMB); Enrique Reef, on mangrove roots, D.L.B. 8986, 21 Jan 1975 (IMB).

Caulerpaceae

Caulerpa ashmeadii Harvey. La Parguera: dredged in 80′, seaward of Margarita Reef, L.R.A. et al. 3762, 15 Sept 1959 (IMB); Laurel Reef 60′, D.L.B., 17 Aug 1976 (IMB).

Caulerpa serrulata (Forsskal) J. Agardh. La Parguera: Media Luna Reef, 12′, R. Zimmerman 7339, 16 Feb 1976 (IMB).

Codiaceae

Penicillus pyriformis A. & E.S. Gepp. Fajardo: on rocks, Bahía de Yeguas, L.R.A. & V.M. Rosado 5083, 28 Apr 1964 (ADE, D, IMB, L, NY, UC). La Parguera: Media Luna Reef, 55′ D.L.B., 28 July 1976 (IMB).

Phaeophyta

Phyllosiphonaceae

Ostreobium quecketii Bornet & Flahault. La Parguera: San Cristóbal Reef, L.R.A 3377, 23 Jan 1959 (IMB).

Sphacelariaceae

Sphacelaria novae-hollandiae Sonder. Guánica: on rocks, L.R.A. et al. 6902, 19 Sept 1973 (IMB). La Parguera: epiphytic, Media Luna Reef, 55′, D.L.B., Apr 1976; 27 May 1976 (IMB).

Tiliopteridaceae

Acinetospora pusilla (Griffiths) Bornet. Guánica: mangrove roots, off San Jacinto, Caña Gorda, L.R.A. & V.M. Rosado 3924, 7 Feb 1961 (COL, D, DUKE, IMB, L, NY, UC, US); Ballena Bay, L.R.A. & V.M. Rosado 4328, 4 Nov 1961 (COL, D, DUKE, IMB, L, NY, UC). Rincón: on rocks, H.L.B. & L.R.A. 3105, 6 Mar 1958 (DUKE, IMB); on rocky ledge, Corcega, L.R.A. & V.M. Rosado 3971, 2 Mar 1961 (COL, D, DUKE, IMB, L, NY, UC, US).

DICTYOTACEAE

Dictyota linearis (C. Agardh) Greville. La Parguera: epiphytic, Media Luna Reef, 55′, D.L.B., 29 Mar 1973 (IMB). Loíza: near Berwind Country Club, Medianía Alta, A. & E. Ortiz 6680, 24 July 1971 (IMB). Yabucoa: A. Rehm 12-71, 27 Jan 1971 (IMB).

CHORDARIACEAE

Cladosiphon occidentalis Kylin. La Parguera: 6′ among *Thalassia*, Margarita Reef, L.R.A. et al. 7278, 8 July 1975 (D, DUKE, IMB, L, NY, UC, US).

SPOROCHNACEAE

Nereia tropica (Taylor) Taylor. Aguadilla: 100′, N. of Ramey Air Force Base, dredged, M.C. Vivas 6850, 4 May 1972 (IMB). Arecibo: Islote, 55′, R. Zimmerman, 22 May 1975 (IMB).

PUNTARIACEAE

Myriotrichia occidentalis Bϕrgesen. La Parguera: epiphytic, 55′, Media Luna Reef, D.L.B., 2 Mar 1976 (IMB).

Hydroclathrus clathratus (Bory) Howe. Cabo Rojo: coral reef, L.R.A. & V.M. Rosado 5100, 30 Apr 1965 (IMB). La Parguera: shallow water, Margarita Reef, L.R.A. & V.M. Rosado 4450, 18 Feb 1962 (COL, D, DUKE, IMB, L, NY, UC, US). Mona Is.: on rocks, Playa Sardinera, L.R.A. et al. 7235, 25 Mar 1975 (D, DUKE, IMB, L, NY, UC, US).

Chnoospora minima (Hering) Papenfuss. Guánica: on rocks, Ballena Bay, L.R.A. et al. 6899, 19 Sept 1973 (IMB). Mona Is.: Sardinera, L.R.A. et al. 7226, 25 Mar 1975 (IMB, NY, UC).

SARGASSACEAE

Sargassum ramifolium Kützing. La Parguera: Media Luna Reef, 55′, L.R.A. et al. 6514, 15 Mar 1971 (IMB, L, NY, UC, US); D.L.B. 11469, 28 Apr 1976 (IMB).

Rhodophyta

BANGIACEAE

Bangiopsis humphreyi (Collins) Hamel. Guajataca: on rocks, outlet of Guajataca River, H.L.B. & L.R.A. 3288, 1 Apr 1958 (ADE, D, DUKE, IIP, IMB, IU, L, NY).

ACROCHAETIACEAE

Acrochaetium sancti-thomae Bϕrgesen. Guajataca: epiphytic on *Chaetomorpha media*, H.L.B. & L.R.A. 3225, 16 Apr 1958 (ADE, D, IIP, IMB, NY).

Acrochaetium seriatum Bϕrgesen. La Parguera: epiphytic, Media Luna Reef, 55′, D.L.B., 19 Feb 1974; Margarita Reef, 80′, D.L.B., Nov 1973 (IMB).

HELMINTHOCLADIACEAE

Liagora megagyna Bϕrgesen. Guayanilla: on sand and rocks, north of Arrecife Gauyanilla, L.R.A. & V.M. Rosado 7073, 10 Aug 1974 (DUKE, IMB, NY, UC).

GELIDIACEAE

Gelidium crinale (Turner) Lamouroux. Aguadilla: on rocks near low tide mark, M.A. Howe 2458, 15 June 1903 (IMB, NY). Guanica: on *Strombus gigas*, 60′, L.R.A. et al. 5491, 17 Feb 1967 (IMB); dredged aboard MRV/Carite, 60′, off Punta Brea, L.R.A. et al. 5557, 27 Mar 1967 (IMB). La Parguera: on coral, Gata Is., H.L.B. & L.R.A. 3128, 10 Mar 1958 (IMB); dredged, 55′, Media Luna Reef, L.R.A. et al. 5654, 1 May 1967 (IMB). Luquillo: on rocks, H.L.B. 12331, 16 Dec 1941 (DUKE). Mayaguez: on rocks, shallow water, Punta Arenas, H.L.B. & L.R.A. 3073, 26 Feb 1958 (IMB). San Juan: on rocks, ittoral, M.A. Howe 2316, 4 June 1903 (IMB, NY); on rocks, Santurce, H.L.B. 12146, 7 Nov 1941 (DUKE); epiphytic on *Digenia*, H.L.B. 12214, 20 Nov 1941 (DUKE); on rocks, Boca de Cangrejos H.L.B. 12913, 21 Mar 1942 (DUKE).

Corallinaceae

Corallina officinalis Linnaeus. Guajataca: on rocks west of tunnel, N. Navarro 6762 July 1971 (IMB, NY, L, UC, US). Hatillo: on rocks, near Urbanización Hatillo del Mar A. & E. Ortiz 6767, 6 Sept 1971 (IMB, NY).

Grateloupiaceae

Halymenia hancockii Taylor. Culebra Is.: on *Strombus pugilis*, M.C. Vivas 5965, Au 1969 (IMB). La Parguera: on *Strombus pugilis*, off Laurel Reef, 60′, D.L.B. 7341 26 Mar 1976 (IMB).

Kallymeniaceae

Kallymenia perforata J. Agardh. La Parguera: dredged off Margarita Reef, 80′ L.R.A. et al. 3807, 17 Sept 1959 (IMB); L.R.A. et al. 11227, 12 Nov. 1973 (IMB).

Rhodymeniaceae

Chrysymenia ventricosa (Lamouroux) J. Agardh. Guayanilla: on rocks 8′-10′, Ventana L.R.A. & V.M. Rosado 4324, 3 Nov 1961 (IMB). La Parguera: dredged, MRV/CARITE Media Luna Reef, 55′, L.R.A. et al. 5500, 28 Feb 1967 (ADE, D, DUKE, IMB, L, NY, UC US). San Juan: washed in on beach, H.L.B. 12491, 27 Jan 1942 (DUKE).

Cryptarachne planifrons (Melvill) Kylin. La Parguera: on algal trap, 80′, L.R.A. & V.M. Rosado 4865, 2 Oct 1963 (IMB); L.R.A. & V.M. Rosado 5059, 18 Feb 1964 (IMB).

Ceramiaceae

Seirospora occidentalis Bϕrgesen. Guanica: 3 mi. off Punta Brea, 50-60′, L.R.A. et al 5409, 12 Dec 1966 (IMB). La Parguera: off Margarita Reef, 80′, L.R.A. & V.M. Rosad 4888, 17 Dec 1963 (IMB); L.R.A. et al. 5753, 15 June 1967 (IMB); Media Luna Reef, 55′ L.R.A. 5998, 25 Sept 1967 (IMB); off Laurel Reef, 60′, D.L.B., 17 Aug 1976 (IMB).

Griffithsia tenuis C. Agardh. Culebra Is.: on mangrove roots, Ensenada Honda L.R.A. & V.M. Rosado 4031, 25 Mar 1961 (COL, D, DUKE, IMB, L, NY, UC, US). Guajataca: on rocks in shallow water, H.L.B. & L.R.A. 3220, 16 Apr 1958 (IMB). La Parguera on algal trap, 50′, L.R.A. et al. 5756, 6 Oct 1967 (IMB); L.R.A. et al. 5989, 25 June 196 (IMB); on algal trap, 80′, L.R.A. et al. 5758 10 Jan 1968 (IMB); Media Luna Reef, 55′ L.R.A. et al. 6015, 25 Sept 1969 (IMB).

Spermothamnion gymnocarpum Howe. La Parguera: epiphytic, Media Luna Reef D.L.B., 19 Feb 1974: 28 Apr 1974 (IMB).

Tiffaniella saccorhiza (Setchell & Gardner) Doty & Meñez. La Parguera: epiphytic Media Luna Reef, 55′, D.L.B., 29 Aug 1973 (IMB); off Margarita Reef, 80′, D.L.B. 26 Aug 1975 (IMB).

Gymnothamnion elegans (Schousboe) J. Agardh. Cabo Rojo: on gastropod, *Vasum muricatum* in *Thalassia* meadow, E. Ortiz 6686, 3 Aug 1971 (IMB). La Parguera: epiphytic on *Rhizophora*, D.L.B., Jan 1967 (IMB).

Taenioma macrourum Thuret. La Parguera: epiphytic, Media Luna Reef, 55′, D.L.B. 1 Oct 1974 (IMB).

Cottoniella arcuata Bϕrgesen. Patillas: epiphytic on *Vidalia*, near gravel beach H.L.B. & L.R.A. 3257, 25 April 1958 (IMB). La Parguera: epiphytic, Media Luna Reef 55′, D.L.B., 19 Feb 1974; 26 Aug 1975 (IMB).

Halodictyon mirabile Zanardini. La Parguera: algal trap, 40′, L.R.A. et al. 5757 30 Oct 1967 (IMB); L.R.A. et al. 6765, 30 Aug 1971 (IMB); epiphytic, off Margarit Reef, 80′, D.L.B. 26 Aug 1975 (IMB).

Rhodomelaceae

Polysiphonia scopulorum var. *villum* (J. Agardh) Falkenberg. La Parguera: on *Acropora*, Turrumote Reef, L.R.A. 3544, 7 May 1959 (IMB). Determined by George H. Hollenberg.

Polysiphonia sphaerocarpa Børgesen. La Parguera: intertidal rocks, Margarita Reef, L.R.A. 3482, 5 May 1959 (D, DUKE, IMB, L, NY).

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Biological Sciences

BIRD COMMUNITIES OF A SOUTH FLORIDA FLATWOODS

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ABSTRACT: *Birds were sampled over a 1-yr period in a south Florida flatwoods habitat. Forty-nine species were recorded: 32 permanent residents; 13 winter residents; and 4 summer residents. The total number of species was high in the fall and winter and low in the spring. Granivores were dominant during the summer, but insectivores were dominant during the winter. Relative to granivores and insectivores, very few omnivorous and carnivorous species were observed. Density and species diversity of birds in the flatwoods were much higher than those reported for North American grasslands but lower than those reported from pine woodland areas in Georgia.*[*]

FEW detailed studies of bird communities exist for Florida (Robertson, 1955; Rohwer and Woolfenden, 1969) and apparently none from the extensive south Florida flatwoods in the south central portion of the peninsula. Most of this region is a sparsely treed grassland or savannah used primarily for grazing of beef cattle. Information on the birds of this area may be of interest from a comparative standpoint because the peninsular environment of Florida supports fewer species than continental areas (MacArthur and Wilson, 1967; Rohwer and Woolfenden, 1969; Robertson and Kushlan, 1974; Miller, 1976) and because this area is so far removed from the major grassland and savannah regions of western North America. Our study was part of a larger project examining the effects of different cattle grazing programs on bird populations. Data were collected by walking transects in natural pasture areas of a large cattle ranch. In this paper, we will: 1) describe the composition of the bird community over one year, and 2) discuss the methodology that went into collecting the data.

STUDY AREA—The study area was located 12.8 km east of Parrish, Manatee County, Florida (Fig. 1) and included 13.1 km^2 of native range. Surrounding habitat was also predominantly native range but had scattered improved pastures and tomato fields. The area represented south Florida flatwoods habitat (Davis, 1943; Frye, 1954; Loveless, 1958; Hilmon, 1964), a grassland with scattered slash pines (*Pinus elliottii* var. densa) and saw palmettos (*Serenoa repens*) interspersed with small ponds or marshes ($<$ 2 ha) and live oak (*Quercus virginianus*) hammocks along small streams. Dominant grasses included wire grasses (*Aristida* spp.), bluestems (*Andropogon* spp.), paspalums (*Paspalum* spp.), and panic grasses (*Panicum* spp.). Pines have been cut on the study area in the past; they may have been more dense than at the present time. Mean density of

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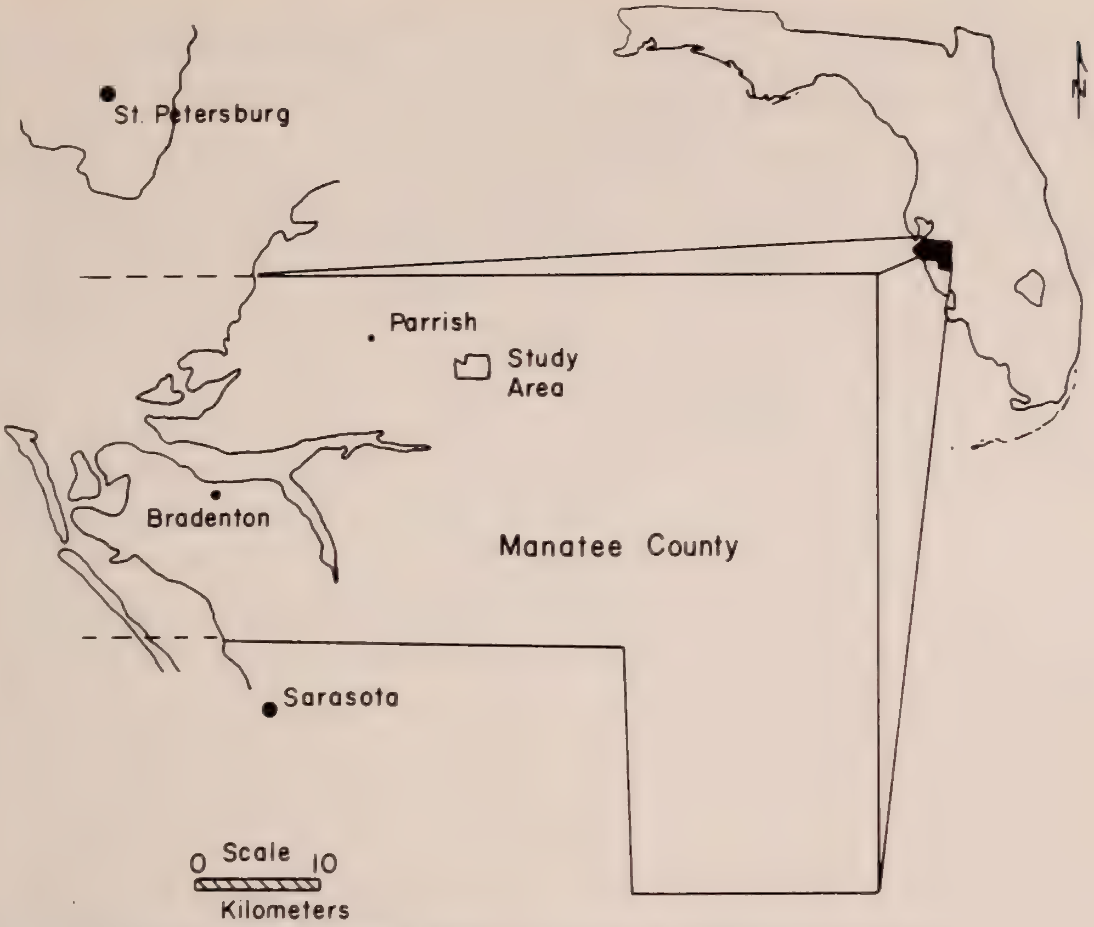

FIG. 1. Location of the study area in Manatee County in west-central Florida.

pines on our study plots was 32.7 (±31.3) per ha with a range of 0-112 trees. At the time of this study, the pastures on this range were being lightly grazed by "escapees" from adjacent pastures.

METHODS—Birds were censused by walking 16 transects located throughout the native pastures of the ranch. Each transect was 221 m long and was the center of a 0.4 ha quadrat. Data from birds seen on the quadrats (i.e., within 9.1 m of the central transect) were used to calculate densities. However, all birds seen or heard from the transects were recorded, and these data were used to determine the relative abundance of birds on the study area. Inclusion of birds seen beyond our quadrats enabled us to record some less common species that were not seen on our quadrats, but which were present at low densities.

Fifteen censuses were conducted in January (4), March (2), June (4), and October-November (5). Observations were made on consecutive days, except for October-November when heavy rains made travel impossible after the second day, and observations were resumed 2 wk later. Counts were begun approximately one half hour after sunrise or as soon as light was sufficient to see. About 3 hr were required to complete all 16 transects. Because time of day influences bird activity and that in turn affects the ability of an observer to detect birds, we reversed the sequence of transects on alternate days. Only 2 access points existed for the pasture systems, and these were at opposite ends of the sequence of transects, which made it impossible from a practical standpoint to further alter the order of the transects.

Bird weights for biomass calculations were obtained from Stewart (1937), Baldwin and Kendeigh (1938), Norris and Johnston (1958), Emlen (1972), and from recorded weights of preserved specimens at the Florida State Museum. Where weights were not available to us, they were estimated. Scientific names of birds were taken from the American Ornithologists' Union Check-list (1957) and 2 recent supplements (American Ornithologists' Union, 1973, 1976).

SPECIES—Forty-nine species of birds were seen from our transects in the flatwoods portion of our study area. These included 32 permanent residents, 13 winter residents, and 4 summer residents. This is probably a conservative estimate of the species present because these birds were seen on or near the transects, and in order to calculate a common index of abundance, we did not go off the transects looking for more species. Number of species was high in the fall and winter and low in the spring (Fig. 2). Other species were seen that were judged to represent only the pond and marsh habitat, rather than the flatwoods, and were excluded from the present analysis for this reason. These species included a variety of herons and egrets, sandhill cranes (*Grus canadensis*), and mottled ducks (*Anas fulvigula*).

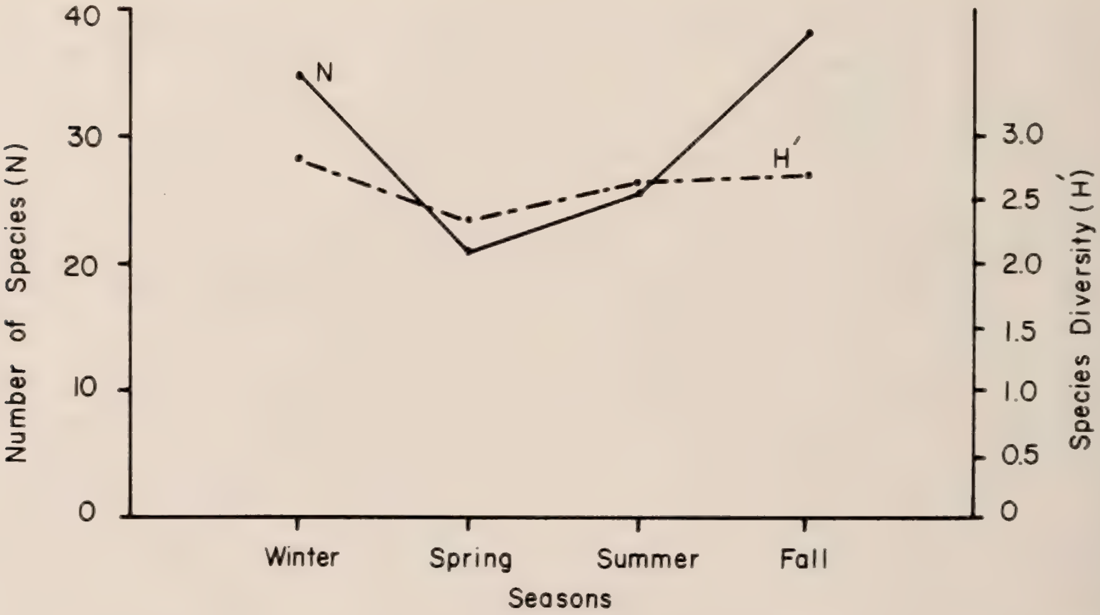

FIG. 2. Total number of species and species diversity of birds observed on the study area according to season.

Density and relative abundance of birds during the January and June sampling periods are in Table 1. These 2 seasons were isolated because they should represent more stable populations than the spring or fall sampling periods, which included at least 7 additional species. A species had to occur on one of our quadrats to have a density calculated, but all flatwoods birds were included in the relative abundance calculation. In general, these estimates of relative abundance paralleled each other, but those species whose behavior was conspicuous to the eye or ear were probably over-represented in relative abundance.

South Florida flatwoods is a savannah habitat, intermediate between a true grassland and a true forest. As might be expected, the bird community of this flatwoods area shares some characteristics of both grassland and woodland habi-

TABLE 1. Density (birds/km^2) and relative abundance of the 42 bird species observed on the study area during January and June.

		January		June	
Species and Feeding Strategies	Season*	Density	Rel. Abun.	Density	Rel. Abun.
GRANIVORES					
Bobwhite (*Colinus virginianus*)	R	54.0	0.058	127.4	0.124
Rufous-sided Towhee (*Pipilo erythrophthalmus*)	R	11.6	0.031	38.6	0.092
Red-winged Blackbird (*Agelaius phoeniceus*)	R	7.7	0.111	77.2	0.108
Mourning Dove (*Zenaida macroura*)	R	3.9	0.012	46.3	0.077
Cardinal (*Cardinalis cardinalis*)	R	--	0.001	3.9	0.001
Ground Dove (*Columbina passerina*)	R	--	--	11.6	0.023
Bachman's Sparrow (*Aimophila aestivalis*)	R	--	--	30.9	0.051
Savannah Sparrow (*Passerculus sandwichensis*)	W	65.6	0.117	--	--
Song Sparrow (*Melospiza melodia*)	W	--	0.035	--	--
		142.8	0.365	335.9	0.476
OMNIVORES					
Common Grackle (*Quiscalus quiscula*)	R	19.3	0.031	27.0	0.018
Boat-tailed Grackle (*Quiscalus mexicanus*)	R	15.4	0.024	--	--
Blue Jay (*Cyanocitta cristata*)	R	11.6	0.033	3.9	0.039
Mockingbird (*Mimus polyglottos*)	R	3.9	0.013	15.4	0.080
Robin (*Turdus migratorius*)	W	11.6	0.048	--	--
Brown-headed Cowbird (*Molothrus ater*)	W	--	0.019	--	--
		61.8	0.168	46.3	0.137
INSECTIVORES					
Eastern Meadowlark (*Sturnella magna*)	R	69.4	0.142	139.0	0.197
Red-bellied Woodpecker (*Melanerpes carolinus*)	R	19.3	0.024	--	0.036
Common Yellow-throat (*Geothlypis trichas*)	R	7.7	0.008	3.9	0.031
Eastern Bluebird (*Sialia sialis*)	R	11.6	0.015	3.9	0.008

Table 1. (Continued)

Species and Feeding Strategies	Season°	January Density	January Rel. Abun.	June Density	June Rel. Abun.
Carolina Wren (*Thryothorus ludovicianus*)	R	7.7	0.010	--	--
Loggerhead Shrike (*Lanius ludovicianus*)	R	--	0.014	23.2	0.030
Red-headed Woodpecker (*Melanerpes erythrocephalus*)	R	--	--	--	0.012
Cattle Egret (*Bubulcus ibis*)	R	--	0.002	--	0.030
Brown-headed Nuthatch (*Sitta pusilla*)	R	--	0.002	--	0.001
Downy Woodpecker (*Picoides pubescens*)	R	--	0.001	--	0.004
Pileated Woodpecker (*Dryocopus pileatus*)	R	--	0.001	--	0.003
Red-cockaded Woodpecker (*Picoides borealis*)	R	--	0.001	--	--
Common Flicker (*Colaptes auratus*)	R	--	--	--	0.003
Pine Warbler (*Dendroica pinus*)	R	46.3	0.046	--	--
Palm Warbler (*Dendroica palmarum*)	W	123.5	0.139	--	--
Short-billed Marsh Wren (*Cistothorus platensis*)	W	3.9	0.001	--	--
Tree Swallow (*Iridoprocne bicolor*)	W	--	0.021	--	--
Common Nighthawk (*Chordeiles minor*)	S	--	--	--	0.012
Eastern Kingbird (*Tyrannus tyrannus*)	S	--	--	--	0.008
Purple Martin (*Progne subis*)	S	--	--	--	0.004
Great Crested Flycatcher (*Myiarchus crinitus*)	S	--	--	--	0.003
		289.4	0.419	170.0	0.382
Carnivores					
Turkey Vulture (*Cathartes aura*)	R	--	0.024	--	0.001
Red-tailed Hawk (*Buteo jamaicensis*)	R	--	0.010	3.9	0.004
Belted Kingfisher (*Megaceryle alcyon*)	R	--	0.005	--	--
Black Vulture (*Coragyps atratus*)	R	--	0.005	--	--
Red-shouldered Hawk (*Buteo lineatus*)	R	--	0.002	--	--

Marsh Hawk (*Circus cyaneus*)	W	--	0.004	--	--
		0	0.048	3.9	0.005
SUMMARY					
Overall Density		494.0	1.000	556.1	1.000
Total Species		18	34	15	27
Species Diversity (H′)			2.84		2.64
Equitability			0.806		0.8004

°R = Permanent Resident; W = Winter Resident; S = Summer Resident.

tats. The most abundant breeding bird, the eastern meadowlark, is a grassland—open field species, but typical brushland and woodland species, such as the rufous-sided towhee, blue jay, and pileated woodpecker, are also common breeders. In addition, other species (e.g., bobwhite, Bachman's sparrow, and red-cockaded woodpecker) characteristic of open southern pinewoods are present. Density and species diversity of birds on our study area were higher than those reported for any grasslands by Wiens (1974), which is not surprising in view of the greater vegetational structure in a savannah habitat. Results of other studies conducted in southeastern pine habitat (Norris, 1951; Johnston and Odum, 1956) are difficult to compare directly to our own because they were based on density of breeding pairs, rather than density of birds during the breeding season.

In a mature longleaf pine (*P. palustris*) stand in southwestern Georgia, Norris (1951) reported 16 species of breeding birds compared to 15 on our quadrats, but the density of breeding birds (974/km^2), a minimum estimate of the total avian population, was almost twice our estimate of total birds present on our study area (556/km^2). In similar pine (*P. caribaea*) savannah habitat in Nicaragua, Howell (1971) reported 15 breeding species and a density of 205 birds/km^2. These 3 pinewoods study sites (southwestern Georgia, southern Florida, and Nicaragua) represent increasing isolation from continental pine forests, have similar numbers of breeding species, but apparently support decreasing numbers of breeding birds. The fact that the number of species does not increase with decreasing latitude may be the result of the peninsular effect in Florida (MacArthur, 1972) and an artifact of a recently created habitat type in Nicaragua (Howell, 1971). However, the decline in density of breeding birds is difficult to explain and is just the opposite of the density trend reported by Karr (1971).

Guilds—Because of their usefulness in classifying species in terms of resource exploitation, rather than taxonomic position, we have separated the species on our study area into food-gathering guilds (Root, 1967; Willson, 1974). The bird community on our study area was dominated by insectivores in the winter and by granivores in the summer (Table 2, Fig. 3). The most important ground-feeding insectivore during all seasons was the eastern meadowlark. During the winter, canopy-feeding insectivores (palm and pine warblers) were abundant, but during the summer, bark drillers and gleaners (woodpeckers and brown-headed nuthatches) were the next largest groups of insectivores after the mead-

TABLE 2. Biomass (kg/km^2) represented by feeding guilds in January and June in comparison to density (birds/km^2). Numbers in parentheses are the proportion of total biomass and density in each guild by season.

	January		June	
Guild	Biomass	Density	Biomass	Density
Granivore	12.8 (.40)	142.8 (.29)	38.2 (.61)	335.9 (.60)
Insectivore	12.6 (.39)	289.4 (.59)	16.5 (.26)	170.0 (.31)
Omnivore	6.7 (.21)	61.8 (.12)	4.3 (.07)	46.3 (.08)
Carnivore	0 (0)	0 (0)	3.9 (.06)	3.9 (.01)
Total	32.1 (1.00)	494.0 (1.00)	62.9 (1.00)	556.1 (1.00)

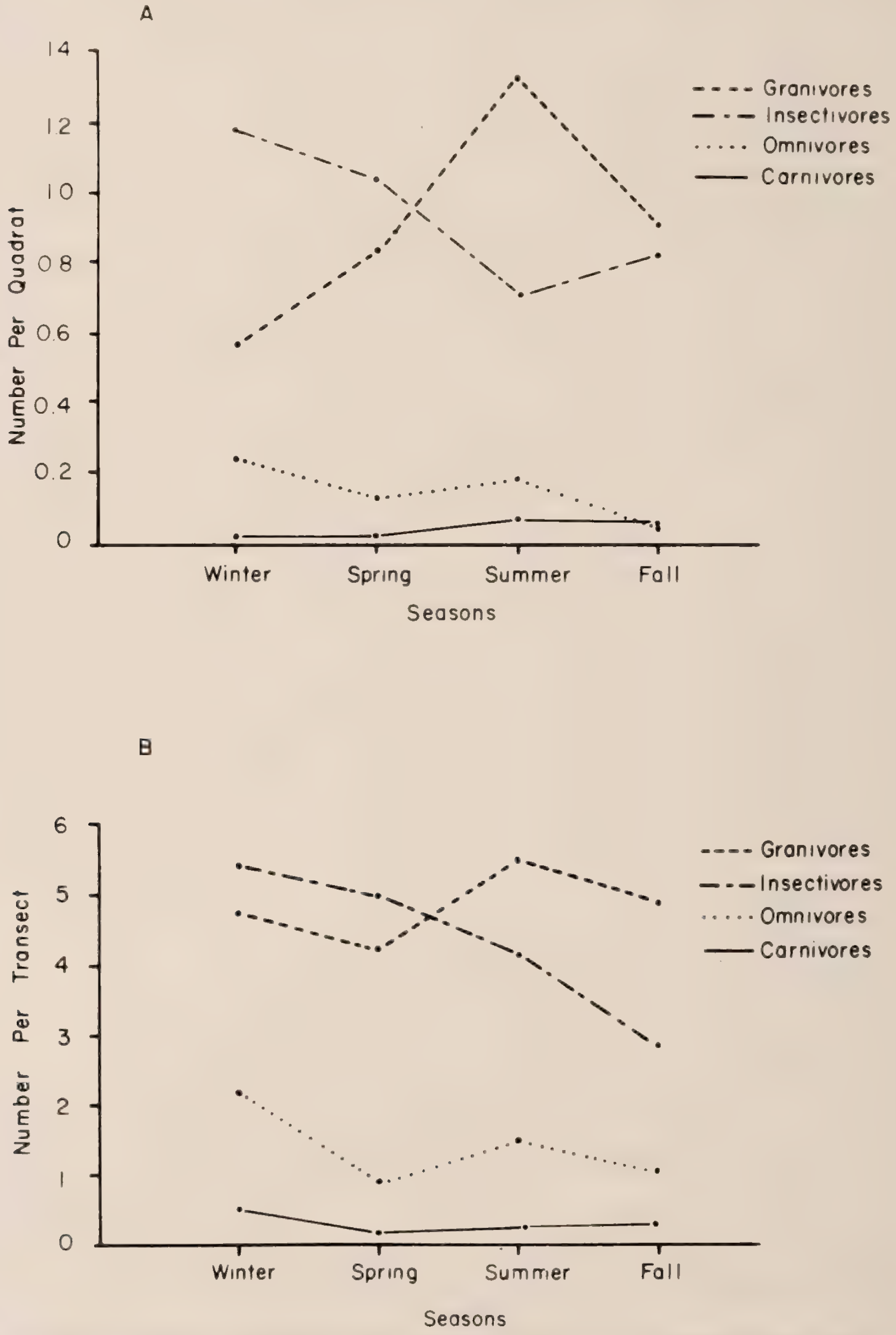

FIG. 3. Seasonal composition of the bird community as measured (A) by density on transect and (B) by overall relative abundance.

owlark. Because the area was primarily a grassland, it was not surprising that granivores formed an important portion of the bird community at all seasons. Most of the granivores were ground-level feeders in open fields, with only the rufous-sided towhee and cardinal representing brushier habitats of saw palmetto and gallberry (*Ilex glabra*). Bachman's sparrow, also a ground-level feeder, was found on transects in open pine woods, as opposed to open grasslands or pine woods with a brushy gallberry understory. The only common granivore present solely as a winter resident was the savannah sparrow, which was abundant in January. Six ground-feeding granivores (bobwhite, red-winged blackbird, mourning dove, ground dove, Bachman's sparrow, and savannah sparrow) were potential competitors for food, and little information seems to be available that would allow finer partitioning of their food resources. In view of the competitive situation that may exist among ground-feeding granivores, it seems inconsistent that only 1 important ground-feeding insectivore was present. Perhaps the above array of granivores also take enough insects to exploit that additional food resource.

Figure 3 presents 2 views of the seasonal composition of the bird community on our study areas, one as determined from birds on the 0.4 ha quadrats, and the other based on all birds seen or heard from the transects. The basic shapes of the curves are similar, but Fig. 3B shows proportionately more granivores in the winter and more insectivores in the summer than Fig. 3A. In both instances, this was due to the presence of a species or groups of species that were easy to detect over a long distance. In the winter this could be attributed to large numbers of red-winged blackbirds; in the summer, however, it was the combined effect of 11 species of insectivores that were present in densities too low to detect on our quadrats but were readily seen or heard from the transects (e.g., woodpeckers and flycatchers).

Biomass—The biomass of birds on the study area almost doubled from January to June (Table 2). Because these biomass data included no species present only during the breeding season, it was clear that this large increase in biomass was the result of reproduction by resident birds that had occurred prior to our June census period. At the same time that the estimated biomass increased 96%, the estimated density of birds increased by only 13%. In fact, increases in density were recorded only in the granivore and carnivore guilds; the other 2 guilds actually lost individuals after substraction of winter migrants. The disparity in biomass and density increases resulted from the simultaneous loss of small winter residents (palm warbler, pine warbler, savannah sparrow, etc.) and reproduction by large-bodied permanent residents (bobwhite, eastern meadowlark, etc.).

Evaluation of the Transect Methods—Many methods have been devised to census bird populations (see Emlen, 1971 for a review). All have advantages and disadvantages; but all have the common failing of being inappropriate for flocking species. Unfortunately, many birds occur in flocks, particularly during the winter or during migration. In this study we have used 2 census techniques, both based on the same line transects. The first one used a long narrow quadrat (18.3 m × 221 m) on which we attempted to detect all birds (type D in Emlen, 1971). This served as a faster method for determining density than the spotmap method used by Noble and Hamilton (1975) and Franzreb (1976) (type C in Emlen, 1971). We chose this density method because of time limitations and because several of the common species on our study area were extremely difficult to flush (e.g., bobwhite and Bachman's sparrow). A disadvantage of the narrow plot method, however, is that a large number of observations have to be excluded from density calculations because they fall outside the quadrat. Another disadvantage of this method is that it works poorly for raptors and aerial insectivores (e.g., swallows and swifts) which are unlikely to land on a quadrat.

With these disadvantages in mind, we also recorded all birds detected while walking the 16 transects in order to obtain an index of relative abundance that would include species that did not occur on our quadrats. Chi-square tests based on the data in Table 1 indicated a highly significant difference ($P < 0.01$) between the relative abundance of birds seen on the quadrats and of all birds seen or heard from the transects in both January and June. In both cases the largest contributions to the total chi-square value were made by 3 flocking species (bobwhite, pine warbler, and palm warbler) that were not visible over a long distance and were disproportionately represented off the quadrats.

Because only 2 sequences existed in which we could cover our transects conveniently and because it took us almost 3 hr to cover all 16 of them, we also were interested in the effect time of day had on the number of birds observed. There was no significant correlation between time since sunrise and numbers of birds seen on the quadrats ($r = 0.0094$, $P < 0.8868$). However, time since sunrise had a highly significant effect on the total number of birds that we detected from the transects ($r = 0.2280$, $P < 0.005$). Apparently, our quadrats were narrow enough that we detected most of the birds on them, usually by flushing, regardless of their degree of activity. Beyond this narrow strip and outside of flushing distance, however, our ability to detect birds was strongly influenced by their activity level, which gradually declined through the morning.

A major problem associated with studies of this type is timing of observation periods. The short duration of the morning feeding and activity period frequently is exceeded by the amount of time required to cover an extensive area. For this reason, investigators needing more than perhaps 2 hr to complete all observations might seriously consider using a narrow-quadrat method, rather than one of the several variable strip methods (Emlen, 1971, 1977; Franzreb, 1976), in which the coefficient of detectability inevitably declines as the morning progresses.

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Education

ACADEMIC STANDARDS AND THE UNDERPREPARED STUDENT IN THE COMMUNITY COLLEGE

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ABSTRACT: *Reasonable and moderate innovation in the curriculum can be useful, but such innovation should not be allowed to reduce academic standards and interfere with the correct evaluation of student performance. A proper mix of traditional education along with limited and proven innovative concepts should yield far better results than much of the change that has so often been employed in recent years under the label of innovation.*[*]

COMPARED with the 1960s, when community colleges and their enrollments were rapidly increasing in numbers, today those institutions, and higher education in general, are simply holding at a steady state. During the earlier years the public rarely questioned the educational philosophy, management, and accomplishments of these institutions. Today they are being questioned from all sides. While the 1960s was a time when government at all levels was willing and able to support higher education almost without limit, the late 1970s finds government not only in financially more difficult circumstances, but also seriously questioning many of the instruction and curricular changes that have occurred during the last 2 decades. For these and other reasons, community colleges, as a part of higher education, are now facing a less optimistic future.

A major reason for the public's concern about curriculum and instruction at virtually all levels of education is because of the serious decline in academic achievements of students at both pre and post secondary educational institutions. For example, Mellander (1977) is rightfully disturbed that academic standards at many community colleges have declined; in some cases drastically. He points out that community college adherents "tell us in quasimystical language that these institutions are part of a growing 'movement' with a 'mission' to provide 'service' to all who come through our doors." Mellander argues that a general deterioration of academic standards has tended to erode public confidence in its support for community colleges, the public schools, and for many 4-yr institutions of higher education. He maintains that at every level of education complaints are more frequent about academic grade inflation, functional illiteracy, and student inability to read, write and compute with any degree of accuracy.

Mellander's complaint has become almost ubiquitous. One has only to look at the recently mandated Florida State-wide test scores of eleventh graders, where over 35% of these Florida students could not pass seventh and eighth grade literacy tests. A public statement by Florida Commissioner of Education Ralph Turlington indicates that the disappointing results of these literacy tests have brought about more public interest and support for education in Florida than any previous event. The depressed academic standards situation exists throughout the nation. Simply to excuse it with arguments claiming that schools and colleges have to deal with more heterogeneous student populations than ever before, that home television is the major culprit, and that modern life is more complex than in earlier times do not justify educators for not succeeding in teaching the basic learning skills. Nor do such arguments excuse community colleges from requiring their students to learn adequate amounts of substantive material.

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[*] The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U. S. C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

For almost 20 yrs now the concept of "change" has been the overwhelming rallying cry which was to improve teaching, especially at the community college level. Classrooms throughout the nation have adopted incredible amounts of innovative procedures, including self-paced learning strategies, non-punitive grading systems, massive use of audio-visual materials, student-directed curricula, open classrooms, permissive attendance policies, simulation games and many others. Yet, in that same time we find seriously declining academic achievement scores along with increasing levels of academic grade inflation. Some of these innovative methods may offer benefit to the learning process under special circumstances. None, however, seems to have produced the great improvement in education which their overly optimistic supporters promised. While many of these innovative ideas were excellent and would have done much to improve classroom teaching, the blame, their supporters often claim, rests with the teachers who often have lacked the skills to make them yield maximum results. To this response one might wonder how much criticism should be put on instructors using some of these innovations and how much lies with the methodologies themselves.

Granted that some innovative teaching devices may have helped in some instances to improve teaching, an inordinate number of others apparently have not, and may even have had a deleterious effect. In many instances concepts such as non-punitive grading and academic grade inflation may have contributed to declining academic standards. Simply to certify that disadvantaged or underprepared students have passed courses when they may not even have come close to such levels of attainment does both the educational institution and the student a disservice.

As annual expenditures for community colleges and for public education in general are at an all-time high, the public is not in a mood to hold teachers and administrators accountable for results, or lack of them, in student learning (Time, 1977). The somewhat valid excuse that the nation's socio-economic problems are more complex than in earlier decades does not satisfy these critics. Results are what count.

There are many rational strategies that can be employed to improve the present unhappy situation in the classroom. For one; let us understand that adding even more innovative teaching methodology will not in itself do much to alleviate the present situation. Few people are opposed to reasonable change in any human endeavor providing that such activity leads to improvement in what already exists. Yet catching students' imaginations by depending upon open classroom teaching, role playing and simulations as such may not materially guarantee comprehensive and improved learning when the need is for increased substantive knowledge and learning skills.

Davis (1977) of University College of the University of Cincinnati asked 22 respondents who attended her session at the Community College Social Science Convention in Atlanta, Georgia to complete a questionnaire. In response to the question "have you tried teaching by means of simulations and role playing," most of the answers were positive. Virtually all of these respondents, who were teachers in community colleges, further explained that the benefits from such teaching strategies had been either negative or at best minimal. Most of the respondents maintained that the lecture-discussion teaching format, at least for the bulk of their teaching methodology, had ordinarily proven superior by any reasonable measure they could devise.

The "open door" admissions philosophy of the community college is a valid one and can work to the advantage of all concerned if this term is not translated into a lowering of academic standards, as is so often the case. Community college instructors can meet the needs of heterogeneous student bodies if they present course material in a highly organized and moderately paced manner. If the teacher speaks clearly, in words understandable to most students in the class, and slowly enough so that people of less than average ability can take notes, reasonable learning will occur in general education courses. The instructor should respond to all reasonable questions. All important are the teacher's clarity of presentation, explanation of material, and moderation of pace.

Before the instructor begins the presentation, it is often useful to include an outline of the day's discussion on the blackboard. This is usually preferable to giving each student a study guide, which too often is simply a sample of a forthcoming test. Further, the use of an outline on the blackboard requires each student to become immediately involved in the subject matter because he must copy it into his notebook. The "handout" study guide does not require such student involvement and may, therefore, become a crutch rather than an aid to learning. In this situation each instructor could employ whichever method he prefers.

Mellander (1977) maintains that if the community college wishes to retain or regain public trust it should not, as is so often the case, "allow students to coast along without written assignments, living in a world of computerized short answer examinations." He is emphatic that they not be allowed to foster grade inflation or a "when I feel like it" attendance policy. Mellander (1977) explains how he reinstated a realistic grading system at Passaic County Community College in 1975 after the college had been allowed to drift with few real standards. He maintains that the institution of a realistic grading system along with a new probation and suspension policy gave the faculty the necessary authority to evaluate students' work and achievements. Also, he said that this gave students a far greater challenge than many had faced before, an opportunity to consciously develop habits that would lead to success.

Most community college students are average or less than average in academic preparation and ability; yet this should not necessitate myriad classes based on ability levels of students. While some extremely high risk students might reasonably be placed in special remedial classes, most should remain in the same sections of their courses. A few classes for students of superior ability might be offered, however. What should be avoided, though, is the establishment of numerous remedial classes which offer credit similar to that which is yielded by the regular classes. The former, as often constituted, have lower achievement requirements and expectations than standard classes. They usually certify that their students have received credit also, credit which can be used for transferring to upper division institutions in many instances.

It is vitally important that classroom testing be both subjective and objective; that is, it should not be limited to the objective format alone, (e.g., multiple-choice, completion, and true/false) as is so often the case in community colleges. Hour long classroom tests which include both subjective and objective formats are probably the best type; each section of a student's test can thus be compared on an individual bases. Alternative objective and subjective type tests may also be suitable. For too many years instructors have frequently employed objective tests exclusively. While such testing formats do allow for almost instant scoring and thus save the instructor many hours in grading time, they do not offer students the badly needed opportunity to present their substantive knowledge and thought processes on paper. Instructors will not be overworked in grading papers if perhaps as little as one third of the test material is subjective in nature and two thirds of the objective variety. While objective testing can examine more individual areas of knowledge, subjective responses can give the teacher many insights about a student's knowledge not available in objective test procedures. In the real world of occupations many of the better jobs require substantive knowledge expressed in written form, not simply an ability to discriminate from several alternatives as represented in multiple-choice responses.

A study I made recently compared the relationship between objective and subjective classroom tests and student evaluations of their instructor (Handleman, 1977). The results of this investigation clearly indicated that 3 quarters of the students will rate their instructor higher if he employs all-objective tests rather than subjective ones or a combination of both. At the same time, most of the students tested admitted that the combination objective-subjective type tests offered a more realistic judgment of student achievement levels than did all-objective tests. This study also clearly showed that the correlation between the objective and the subjective sections of each student's test was not so great as one might assume. This would suggest that all-objective tests may not be so valid as "combination"-type tests. For these and other reasons already mentioned, there is a strong case in support of both subjective as well as objective examinations. The serious erosion of student writing skills during the past 15 or more years further corroborates this position.

Studies have been made in recent months indicating that moderately traditional teaching strategies yield better results than many innovative ones—even for disadvantaged and high risk students. Mellander's (1977) experience at Passaic County Community College, noted above, states that 468 students at that institution, almost one third of the entire student body, were either suspended or placed on probation when realistic grading was reintroduced at that institution in 1975. He explained that the previous "non-punitive" grading system—no D's, no F's—had been proven a failure. As a result of the new and more stringent grading formula, said Mellander, Passaic Community College "risked serious financial constraints, public animosity and widespread distortion of our purpose and goals." But he pointed out that "these decisions were preferable to maintaining an 'educational charade.' " The result of this change, however, was that enrollments soon afterwards increased, the faculty supported the decisions, and the public soon offered wide-spread support. The students reacted very favorably, and "the college is now on its way to establishing an academically sound institution."

The public schools and the community colleges can succeed in educating most students at reasonable levels of achievement in general education if greater emphasis is placed on basic learning skills and on substantive knowledge. It is not true, as some critics would have us believe, that such a thrust would lead to elitism in education; that the high risk and disadvantaged student would thus be forgotten. Most students are inspired after they have made a real effort in their studies and when their learning levels increase. Improving students' learning in the affective domain at the expense of the cognitive, as has often been the case during the past decade and more, is not the way to upgrade institutions of education.

Some critics claim that public schools give in to teenagers' desires to be entertained. They maintain that, consequently, homework and course requirements have gone down while grades have gone up. As a result, many states have now passed laws requiring competency exams, and Congress has also begun hearings on whether there should be a nationwide competency exam.

The valid issue of demanding at least reasonable academic standards has, unfortunately, become enmeshed in the civil rights controversy. Innumerable cases have been brought before the courts arguing that mandating standardized and other types of test performance is simply a strategy which will do harm to the educational opportunities of disadvantaged and minority groups in this country. Sherman (1976) of the State University of New York at Albany sees the situation otherwise. He maintains that those people who wish to help the disadvantaged student would be wiser to stress, not disparage, intellectual values and academic standards. Sherman claims there is a strong correlation between student achievement and teachers' scores on short (30 word) vocabulary tests; that upgrading teacher academic skills and knowledge would especially benefit minority students.

Lest it be thought that all minority leaders are in the forefront for lowering academic standards and for opposing competency testing, the Reverend Jessie

Jackson, a black leader from Chicago, and Kenneth Clark, the eminent psychologist and black leader, have been outspoken in their demand for higher academic standards in the schools and colleges. Jackson maintains that many students are falsely certified, that they are functionally illiterate at graduation from secondary school and that they are passed off as functionally literate (Jackson, 1977).

Improving academic standards in the public schools and colleges, including community colleges, would benefit high risk and traditional students alike. Employers would again give respect to high school and college diplomas. They would become willing to hire these people because graduation would represent respectable academic and career levels of achievement. One of my previous investigations concerns faculty views on curriculum and instruction at 5 different community colleges. This study indicates that approximately three quarters of the randomly selected respondents (74 total) believe that phenomena such as academic grade inflation, erosion of academic standards with the consequent reduced emphasis on cognitive learning may have been, to a substantial degree, the consequence of many unproven innovative teaching strategies which have not lived up to the promises of their optimistic and overly zealous sponsors (Handleman, 1976).

In conclusion, it should be realized that the serious problems in education that have been discussed will not disappear as a result of the introduction of still more innovative teaching strategies. As already mentioned, a few of these methods on occasion may be of some benefit in specific instances. Yet, all of the "hardware" and "software" in the world will not insure that students subject to their offerings will be materially better served than those who are taught by more conservative methods. Well prepared, demanding and dedicated instructors who carefully and slowly present subject matter in classes of average and mediocre community college or public school students are the bases around which real learning and understanding can be achieved. Of course, limited amounts of audiovisual materials and innovative methodology have a place in the classroom if such materials and teaching strategies are recognized for what they are—secondary aids which may to a degree in some instances complement the main strategies for learning—accomplished teaching and willing students. People become willing students when they notice that their teachers are serious and hardworking, willing to grade written assignments and tests. Such students realize that they are actually learning substantive material and not simply that which appears in the affective domain of learning. These students will often become inspired to higher levels of achievement; they will better be able to relate their learning to the real world of work and study. They will learn to discipline themselves rather than always to depend on the "entertainment" that goes on in the classroom. They will gain self-respect for the knowledge and skills they have obtained in an institution that requires solid achievement rather than permitting an accommodation to students' undisciplined inclinations.

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Biological Sciences

SPECIES ASSEMBLAGES OF FISH IN LAKE CONWAY[1]

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Abstract: *A species association index based on presence–absence data was used to identify 5 species complexes on Lake Conway, Florida. These complexes include* Lepisosteus platyrhincus–Pomoxis nigromaculatus, Micropterus salmoides–Lepomis macrochirus, Dorosoma petenense–Labidesthes sicculus, Gambusia affinis–Lucania goodei, *and* Lepomis gulosus–Enneacanthus gloriosus *associations. The 2 species with the largest index of affinity bear the complex name. All complexes were correlated with basic habitat features. Species pairs with the largest individual affinity indices included* Dorosoma petenense—Labidesthes sicculus, Lucania goodei—Gambusia affinis, *and* Micropterus salmoides—Lepomis macrochirus.°

Traditionally, studies of species assemblages have subjectively grouped species with similar distributional patterns. More recent theoretical approaches have emphasized mathematical techniques in analyzing community structure and interspecies relationships. Smith and Fisher (1970) and Stevenson et al. (1974) described species groups by factor analysis for ichthyofauna of Kansas and western Oklahoma, respectively. On a smaller scale, Smith and Powell (1971) and Echelle and Schnell (1976) analyzed species associations of fish in Brier Creek, Kansas and Kiamichi River, Oklahoma, respectively.

The species assemblages of fish found in lacustrine habitats have never been determined. In this paper I mathematically analyzed the species assemblages of fishes inhabiting Lake Conway and correlate the distribution of these complexes with basic habitat features.

Study Areas—This research was conducted in the Lake Conway chain of lakes near Orlando, Florida. The chain, a part of the Kissimmee river drainage system, totals 728 ha. The shoreline has been altered by urbanization and associated shoreline development, with much vegetation having been removed. Some areas have retained a narrow fringe of emergent *Panicum*, *Typha*, or *Fuirena*. Dominant submergent vegetation includes *Vallisneria*, *Potamogeton*, *Nitella*, and *Hydrilla*. The substrate is primarily sand, except in areas of extremely dense vegetation where a thick layer of organic detritus has built-up. The lake is mesotrophic. The bottom contours are steep in some areas.

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METHODS—Six sampling methods were used to collect the fishes from May through September 1976. Five blocknet samples were taken in June 1976. A sinking and floating gill net (124 m long) were set overnight at each of 4 stations monthly. Six sampling stations were established for each remaining gear type; sampling occurred monthly. Two Wegener ring (Wegener et al., 1974) samples were taken at each station in shallow, densely vegetated areas. Two seine collections accompanied Wegener rings at each station. One collection was taken in unvegetated habitats with a 6.1 m seine, while the other collection was taken adjacent emergent vegetation with a 3.0 m seine. Thirty minutes of nocturnal electrofishing occurred monthly at each of 3 vegetated and 3 unvegetated shoreline areas.

The affinity between pairs of species was determined using an index of species association (C) utilizing presence-absence data for all collections: $C = 2aJ/b(a + b)$, where J equals the number of joint occurrences of species a and b and a and b are the number of times species a and b were encountered, respectively. This index ranges from 0.0-1.0, with 1.0 indicating complete association in all samples and 0.0 reflecting a negative association.

Species groups were then determined after indices of affinity had been calculated for all species pairs. An index of 0.15 was chosen as the minimum value for 2 species to be considered associated. The formation of species assemblages was based on the following criteria: 1) every species within a group must show affinity with all members of the group, thus ensuring that every taxon in a group frequently occurs with every other member; 2) the largest possible groups must be formed in sequence; and, 3) species of the first assemblage are excluded in the determination of the second group, with species of each succeeding group likewise excluded from further grouping. This process was repeated until all possible groups had been identified. The degree of association between each group was expressed by the ratio between the observed number and the maximum possible number of intergroup species showing affinity.

RESULTS AND DISCUSSION—Analysis of joint occurrences by the species association index demonstrated 5 major complexes of positively associated fishes among the 29 species found in Lake Conway (Table 1). I refer to these as the *Lepisosteus platyrhincus–Pomoxis nigromaculatus*, *Micropterus salmoides–Lepomis macrochirus*, *Dorosoma petenense–Labidesthes sicculus*, *Gambusia affinis–Lucania goodei*, and *Lepomis gulosus–Enneacanthus gloriosus* associations. The 2 species with the highest index of affinity bear the complex name.

Species not grouped in any of the above complexes, but which showed affinity to one another included the following: *Lepomis punctatus* to *Amia calva*

TABLE 1. Species groups in Lake Conway.

Group I	
Lepisosteus platyrhincus	*Notemigonus crysoleucas*
Dorosoma cepedianum	*Pomoxis nigromaculatus*
Esox niger	
Group II	
Fundulus seminolis	*Lepomis microlophus*
Lepomis macrochirus	*Micropterus salmoides*
Group III	
Lucania goodei	*Etheostoma fusiforme*
Gambusia affinis	
Group IV	
Dorosoma petenense	*Labidesthes sicculus*
Notropis petersoni	
Group V	
Ictalurus nebulosus	*Lepomis gulosus*
Enneacanthus gloriosus	

and *Erimyzon sucetta*; *Lepomis marginatus* to *Erimyzon sucetta* and *Heterandria formosa*; and *Amia calva* to *Ictalurus natalis*. Other species found in Lake Conway included *Lepisosteus osseus*, *Anguilla rostrata*, *Esox americanus*, *Ictalurus catus*, *I. punctatus*, *Noturus gyrinus*, *Fundulus chrysotus*, *Jordanella floridae*, *Elassoma evergladei*, and *Lepomis auritus*.

Eleven species combinations had index values of 0.40 or greater. *Dorosoma petenense–Labidesthes sicculus* (0.67) and *Lucania goodei–Gambusia affinis* (0.64) had the highest degree of affinity. They were followed by *Lepomis macrochirus–Micropterus salmoides* (0.56) and *Dorosoma petenense–Esox niger* (0.50). Other combinations included *Dorosoma petenense–Notemigonus crysoleucas* (0.42), *Esox niger–Notemigonus crysoleucas* (0.41), *Esox niger–Labidesthes sicculus* (0.42), *Fundulus seminolis–Lepomis macrochirus* (0.46), *Heterandria formosa–Lepomis marginatus* (0.40), *Enneacanthus gloriosus–Lepomis gulosus* (0.44), *Lepomis microlophus–Micropterus salmoides* (0.44), and *Lepisosteus platyrhincus–Pomoxis nigromaculatus* (0.45).

Much overlap existed among species of the 5 groups; they were often taken together so that each complex usually occurred with individuals of one or more of the other groups. Two combinations have a low ratio between the observed number and maximum number of species showing intergroup affinity: *Lepisosteus platyrhincus–Pomoxis nigromaculatus* and *Gambusia affinis–Lucania goodei* complexes with a value of 0.00; and *Micropterus salmoides–Lepomis macrochirus* and *Lepomis gulosus–Enneacanthus gloriosus* associations with a value of 0.08. The highest intergroup relationships were shown by the following:

L. platyrhincus–P. nigromaculatus and *Dorosoma petenense–Labidesthes sicculus* (0.47); and *M. salmoides–L. macrochirus* and *G. affinis–L. goodei* (0.42). Values for other intergroup combinations ranged 0.22–0.23.

It is evident that these species combinations are not well-segregated ecological units; nevertheless, the groups are associated with distinct habitat types to some extent. The relationship between fish distribution and habitat features is often obscured by the lack of specific information concerning the environmental tolerances and responses of various species, and the range of environmental conditions occurring in different habitats. Furthermore, environmental factors are not independent variables, and it is rarely possible to demonstrate that one factor is of overriding importance in controlling the distribution of a given species. Nevertheless, I show correlations between the distribution patterns of each species assemblage and obvious habitat features.

The *Micropterus salmoides–Lepomis macrochirus* complex (group II) included the 4 most frequently encountered species in Lake Conway. Of a total of 173 samples with all gear types, *M. salmoides* was collected 93 times, *L. macrochirus* 82 times, *Fundulus seminolis* 81 times, and *L. microlophus* 58 times. In discussing other species assemblages, I relate their distributions to basic habitat features; however, in discussing the above ubiquitous species, it is appropriate to consider why they are not similarly restricted. It is logical to assume that they have broader environmental tolerances than do the more restricted species. With the exception of *F. seminolis*, which attains its peak of abundance on sandy, nonvegetated littoral habitats, these species show no obvious habitat preferences. They occur over all bottom types, at all depths, and in areas with and without vegetation. Therefore, the members of the *M. salmoides–L. macrochirus* complex occur with regularity with the other species groups.

Members of the primary species group, the *Lepisosteus platyrhincus–Pomoxis nigromaculatus* complex (group I) are inhabitants of open water areas and the deeper littoral zones. *Dorosoma cepedianum*, *Notemigonus crysoleucas* and *P. nigromaculatus* are schooling species and characteristic of open water, whereas *L. platyrhincus* and *Esox niger* typically occur in deeper littoral habitats. Six species, not included in this complex because of their infrequency of occurrences in the samples, have similar habitat preferences to the *L. platyrhincus–P. nigromaculatus* complex: *Amia calva*, *Erimyzon sucetta*, *Lepomis marginatus*, and *Lepomis punctatus* are found in deep littoral habitats adjacent to thick emergent vegetation; *Ictalurus catus* and *I. natalis* occur in open water.

Because their habitat preferences overlap, the *Lepomis gulosus–Enneacanthus gloriosus* (group V) and *Gambusia affinis–Lucania goodei* (group III) complexes are discussed together. Both groups prefer dense stands of aquatic vegetation in littoral habitats less than 1 m in depth. The *L. gulosus–E. gloriosus* complex, however, is most often encountered over soft, organic substrates in water over 30 cm in depth where submergent vegetation dominates. On the other hand, the *G. affinis–L. goodei* assemblage is more ubiquitous in shallow densely vegetated areas; this complex, however, is most abundant in water less than 30 cm in depth. Three other species (*Heterandria formosa*, *Fundulus chrysotus*, *Jordanella floridae*) that occurred infrequently with the above groups also prefer dense stands of littoral vegetation.

Members of the *Dorosoma petenense–Labidesthes sicculus* complex (group IV) are most characteristic of clean, sandy–bottom, wave–washed shorelines frequently devoid of vegetation. Although *D. petenense* is generally an open water species, in Lake Conway it is more prevalent in the habitat described above.

Although mathematical analyses of species associations allow large sets of data to be reduced to small components, thereby expediting objective assessments, there are 3 basic limitations in their use: 1) certain species, because of their rarity, may not be mathematically associated with a species complex but be ecologically associated with the same habitat; 2) 2 competing species may exclude one another from association with a given species group at a sufficient number of localities to depress the correlation with that group; and 3) if a species is difficult to collect, its appearance in the samples may not be representative of its actual distribution. Despite these limitations, I feel that species association indices are useful in determining the ecological relationships between various species.

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Mathematical Sciences

SOME MATHEMATICAL ASPECTS OF THE PHILOSOPHY OF SPACE

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ABSTRACT: *I discuss 2 topics in the philosophy of space which are related to fundamental questions in mathematics: the dimensionality of the space continuum and Zeno's arrow paradox. For the former, it is demonstrated how the discipline called dimension theory in topology, coupled with real-world data, completely settles the question, though not without some subtlety. However, for the latter it is argued that the explication offered by rigorously formulated differential calculus, though logically unassailable, actually skirts the phenomenological issue, which is discussed and tentatively identified.*[*]

THIS article explores some aspects of mathematics which relate to two questions in the philosophy of space. The first question is the dimensionality of the spacial universe; this surely ranks as one of the least crucial issues in modern metaphysics, and thus (naturally) it is the one most susceptible to mathematical reasoning. But it is perhaps interesting, possibly even amusing, to observe the topological gymnastics that had to be developed to lay this question securely to rest, followed by the emergence of a surprising result from applied mathematics which enhances the overkill aspect of the analysis.

The second question to be discussed is Zeno's arrow paradox. Here I attempt to determine, definitely, the status of the paradox in relation to the rigorous formulation of differential calculus. The conclusions, if not new, at least might be useful in providing a better perspective for evaluating the prolific activity that has been directed in this area.

Probably the best-known argument which deals with the number of spacial dimensions, n, in the space-time continuum is that of Bertrand Russell. It may be paraphrased as follows: on the one hand, our best experimental evidence seems to be consistent with the value $n = 3$. On the other hand, n obviously must be an integer, and thus there is no possibility of our being in error by only a few per cent as is inevitable in measurements of other physical parameters like the speed of light, Planck's constant, etc. Hence we are justified in claiming that n is, definitely, 3.

I would like to elaborate on the premise of this argument, namely, that the evidence points to the value $n = 3$. To analyze this statement critically requires a very careful definition of the meaning of n, the number of spacial dimensions.

To avoid any relativistic *faux pas*, I shall focus on an observer equipped with a Lorentzian frame of reference, and consider all the events in the space–time continuum in relation to him (whether or not they are causally influenced by

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him); then I restrict to the subclass of these events which he considers to occur "simultaneously" at some arbitrary fixed time. The events in this subclass constitute the "points" in his spacial universe, and I want to formulate a precise definition of the number of dimensions for this space of points.

A first try at this is derived from the experience of giving directions to "the man on the street." He asks how to find some location, and he is told to go 7 blocks east, 3 blocks north, up 4 flights of stairs and 3 doors down the hallway to the right. Of course, there is redundancy in these data; if he is willing to use the back entrance to the building, he could go 2 blocks north and take the 9th door down the hallway on the left. But if he happens to be adequately equipped (with compass, odometer, altimeter, laser guns, etc.) he could be told, efficiently and unambiguously, that his destination is located 2310 ft east, 907 ft north, and 64 ft straight up. This is unambiguous because any other nearby combination of 3 numbers, interpreted as ft east, ft north, and ft straight up, would lead him to a different destination. (The adjective "nearby" is inserted for purists, to dispel the possibility of his encircling the globe before getting down to business.) And this is efficient because there seems to be no scheme for directing him to an arbitrary destination which employs fewer than 3 numbers.

A seemingly reasonable definition of the dimension, n, can be extrapolated from this experience. One considers all the possible schemes which the observer can use to designate, numerically, the points in his spacial universe; from these there must be some which employ a minimum number of parameters to locate each point (so that the other schemes must involve some redundancy). This minimum number of parameters is then taken to be the dimension of the space.

In order to analyze this definition it must be expressed in more mathematical language. A paraphrase of the preceding paragraph would be as follows. Let E^m ("Euclidean m-space") denote the set of all m-tuples of real numbers $[x_1, x_2, \ldots, x_m]$. Consider, for each m, the class F^m of all the functions which map E^m *onto* the spacial universe (i.e., *each* point in the latter occurs as the image, under the function, of some point in the former). If, for some n, F^{n-1} is empty but F^n is nonempty, then n is the dimensionality of the space.

To apply this, observe there are many ways of designating every point in our known universe by 3 parameters (e.g., Cartesian coordinates or spherical coordinates). On the other hand, there are apparently no mappings from E^2 which cover the entire universe (the obvious ones only cover a plane or a surface). One concludes that $n = 3$.

Unfortunately, this intuitively appealing definition has a fatal flaw, because there exist functions from E^1 which cover E^m, for every m; thus, by functional composition, *every* spacial universe can be covered by a mapping from E^1. As a result, every space (including E^m itself) would have dimension one!

To see this, consider the following mapping from E^1 to E^3. First write r as an infinite decimal, adding zeros if necessary:

$$r = \sum_{i=-\infty}^{\infty} r_i 10^i, \qquad r_i = 0, 1, 2, \ldots, 9$$

with, of course, all $r_j = 0$ for large j. Then the image of r is the triple

$$x = \sum_{i=-\infty}^{\infty} r_{3i} 10^i$$

$$y = \sum_{i=-\infty}^{\infty} r_{3i+1} 10^i$$

$$z = \sum_{i=-\infty}^{\infty} r_{3i+2} 10^i$$

For example if $r = 1234.567890123$, then

$$x = 14.703$$

$$y = 3.692$$

$$z = 2.581$$

Observe that all of E^3 gets covered by this mapping; for example, the triplet

$$x = .1111$$

$$y = .2222$$

$$z = .3333$$

is the image of

$$r = .321321321321$$

Thus, using this trick we can pack all the information contained in 3 parameters, into one parameter. Hence we can locate any point in the spacial universe by a single number; but surely we are reluctant to accept the conclusion that our world is one-dimensional.

In passing we mention that the well-known ambiguity in representing a number by its decimal expansion only enhances our argument; it implies that E^1 covers E^m more than once. Secondly, certain cosmologists would insist that we only deal with mappings which are defined locally, but the above discussion is easily modified to satisfy this requirement.

It was shown by Brouwer in a paper of profound significance in topology (Hurewicz and Wallman, 1948) that in order to derive a sensible notion of dimension one should consider, as candidates in the search for the aforementioned minimum, only functions which are one-to-one and bicontinuous (i.e., the inverse is also continuous). The result is known as Brouwer's Theorem of Invariance of Domain and is fundamental for one school of thought in that discipline of topology known as dimension theory.

There is another school of thought in dimension theory which considers a more geometrical, rather than analytic, explication of the concept of dimension. To avoid technicalities, the boundary of a point set may be taken as primitive.

Thus the boundary of a line segment is its end points, the boundary of a square is the 4 segments constituting its perimeter, and the boundary of a cube is its 6 square faces. Very loosely speaking, the concept of dimensionality is then defined inductively as follows: a point set consisting of a finite number of points is 0-dimensional, and any point set has dimension one higher than that of its boundary. Hence a line segment is 1-dimensional, a square is 2-dimensional, and a cube is 3-dimensional. Because cubes do appear in our world, but they do not occur in the boundaries of any known worldly objects, the conclusion is that our spacial universe is 3-dimensional. This is a most satisfactory result after the disquieting revelations of the previous discussion.

There is an amusing "in-joke" among applied mathematicians concerning the number of spacial dimensions, and we present it here without attempting to evaluate its merit.

The propagation of an electromagnetic disturbance ϕ proceeds, according to Maxwell's equations, in accordance with the "wave equation":

$$\frac{\partial^2 \phi}{\partial x^2} + \frac{\partial^2 \phi}{\partial y^2} + \frac{\partial^2 \phi}{\partial z^2} = \frac{1}{c^2} \frac{\partial^2 \phi}{\partial t^2}$$

(Jackson, 1962). Here $\phi(x, y, z, t)$ is the disturbance at the point with Cartesian coordinates (x, y, z) at time (t), and c is the speed of light. Now the remarkable thing about this equation is that it is relativistically covariant, i.e., consistent with special relativity. And it seems an obvious extrapolation to assume that, in an n-dimensional world, electromagnetic disturbances would propagate according to the covariant equation

$$\frac{\partial^2 \phi}{\partial x_1^2} + \frac{\partial^2 \phi}{\partial x_2^2} + \cdots + \frac{\partial^2 \phi}{\partial x_n^2} = \frac{1}{c^2} \frac{\partial^2 \phi}{\partial t^2}$$

This equation can be solved, for any n, to find the disturbance ϕ at any point created by a distant point source emitter, such as a TV station. But the solution has remarkable properties for different n (Courant and Hilbert, 1961). It turns out that for $n = 1$ or 3, the solution at any point is similar in time to the signal being emitted. Of course there is a delay while the wave is propagating from source to detector, and for $n = 3$ (but *not* 1) the amplitude decays during the propagation, but the detected disturbance, suitably amplified, exactly matches the emitted signal. If n is any other odd number, the detected disturbance contains a superposition of the emitted signal and its derivatives, all added in with coefficients which vary with distance from the emitter. Thus while it might be possible in this case to build a device which would filter out the emitted signal at one location, the device would not work properly if the location were changed. The situation for even numbers n is even worse–the detected signal bears little resemblance to the emitted signal. In fact, the former continues to exist even after the emitter has been turned off!

This effect can be visualized for n = 2. A 2-dimensional world can be modeled in 3 dimensions by considering configurations which are invariant in, say, the z-direction; thus all z-derivatives are zero. A point source of light in 2 dimensions corresponds to an infinite line source in 3 dimensions (e.g., an infinitely long neon tube). If the detector is placed some distance away from the tube, no light reaches it before the bulb is turned on, nor for a short while after. But long after the tube is turned off, the detector will still be receiving light emitted earlier by the distant "ends" of the tube.

As a result one could conclude that television broadcasting would be impossible in a world where n is even, and portable televisions would be impossible for n odd and greater than 3, while if n = 1 local programming would be impossible (faraway signals would not die out). This leads to the Panglossion conclusion that n = 3 because surely the best of all possible worlds would have television.

Now Zeno's arrow paradox will be considered. The problem is as follows: can an arrow in flight have both a position and a velocity at a given instant? That is, can one conceptually "freeze" time at some specific value, thus freezing the position of the arrow, without also conceptually annihilating its state of motion?

Observe first of all that the concept of velocity as explicated by the differential calculus involves no paradox. The trajectory of the arrow is specified by a functional relationship x = x(t), giving the position of the arrow (x) at any time (t). Postulating the function x(t) entails acceptance of the notion that one *can* conceptually freeze the motion, so that the arrow *does* occupy a unique position at any time (t); indeed, this axiom underlies the concept of the space-time continuum.

Now calculus defines the velocity of the arrow to be the limit of a set of difference quotients:

$$V = \text{limit } \frac{x(t+\Delta t)-x(t)}{\Delta t} \quad \text{as } \Delta t \rightarrow 0.$$

Observe that this is operationally sound. The difference quotients are all computed in accordance with the frozen-position interpretation, and the limit of a set of numbers is a purely logical concept, using the Cauchy criterion. Hence, with this point of view, one has assigned the properties of velocity to the arrow's trajectory while clearly side-stepping the question of whether or not the arrow "has motion" when its position is conceptually frozen. The definition achieves exactly what a purist would demand; it is absolutely sterile with respect to any dynamic imagery. One cannot hold that it is paradoxical for position and "velocity" to exist simultaneously without also contending the impossibility of the simultaneous existence of the n^{th} and $(n+1)^{st}$ derivatives of a function.

Why, then, does Zeno nonetheless instill a feeling of uneasiness with his argument? The reason is, of course, that this definition is just too abstract. The human experience provides an intuitive feeling for the concept of velocity, and it is not immediately clear that the above equation expresses it. One should consider the various ways in which velocity is measured, physically, and compare them with the calculus definition.

The first method that comes to mind involves stationing 2 observers with stopwatches next to each other. They clock the time when the arrow passes by, and then divide the separation distance by the elapsed time. The accuracy of the result is refined by placing the observers closer together. Obviously this is a direct implementation of the above equation and thus it cannot lead to any disillusionment with the frozen-position interpretation.

Alternatively, one may take a motion picture of the arrow's flight, and subsequently analyze the film. Surely no trouble arises here, because each frame of the film is a perfect physicalization of the frozen-position concept.

Even the concept of velocity as derived from visual perception, i.e. simply watching the arrow fall, cannot honestly lead to any dissatisfaction with the equation, because the mechanics of the sight process employs the frozen-position concept; the optic nerve delivers its data to the brain by firing discrete neurons.

The key to the source of one's skepticism regarding the calculus definition of velocity is the acknowledgment that there is another, more primitive, notion of velocity which is *derived* from a more basically perceived concept: that of momentum. It is the momentum, not the velocity, of the arrow that measures its destructive potential. It is the momentum, not the velocity, that registers as basic tactile data when it strikes its unfortunate target. And when one observes the curvature effect that a force field exhibits on its trajectory, it is the interaction of the force with its momentum, via Newton's law, that is responsible. Velocity, in this context, merely arises as one of the components of this more fundamentally perceived notion; inertia, of course, is the other.

If one were to extract a conclusion from these observations, it would be this; one should recognize that Zeno's qualms about the simultaneous existence of a definite position and a state of motion of the arrow do not arise because of a dissatisfaction with the concept of velocity, but rather they are tied to his basic feeling for momentum. This simple observation, however, is extremely suggestive, because the position-momentum rivalry permeates modern physics. In classical Hamiltonian mechanics, for example, position and momentum are canonically conjugate variables, while in wave mechanics their duality is even more pronounced. In this regard one is led to speculate that Heisenberg's Uncertainty Principle, a basic postulate of quantum theory which prohibits the simultaneous specification of both position and momentum, may have ancestral roots in ancient Greek philosophy.

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IMPACT OF WINTER COLD FRONTS UPON SHALLOW-WATER REEF COMMUNITIES OFF WEST-CENTRAL FLORIDA—*L. H. Bullock and G. B. Smith*, Marine Research Laboratory, 100 Eighth Avenue S.E., St. Petersburg, Florida 33701

Abstract: *Shallow-water (12-37 m) eastern Gulf of Mexico reef biotas suffered damage during the exceptionally cold winters of 1977 and 1978. Certain fishes were killed or sustained injury either directly from the cold or from physical abrasion against the reef during heavy bottom surge accompanying cold front passage. Reef corals were overturned or torn from their reef attachment during periods of heavy bottom surge. Recovery time for these impacts is not known.*°

The nearshore shelf off west-central Florida has a gentle slope; the 18 m isobath lies 26-27 km off Tampa Bay. This shelf interval is characterized by sand-shell substrates sporadically interrupted by low relief ($<$ 3 m) limestone reefs. These reefs, harboring a rather diverse biota dominated by tropical species, are described by Phillips and Springer (1960) and Smith (1976). Most limestone outcrops off west Florida assume the form of undercut ledges paralleling existing depth contours and undoubtedly represent relict shoreline features. These habitats are usually associated with a diverse assemblage of algae, alcyonarian and scleractinian corals, hydrocorals, sponges, echinoderms, crustaceans, and other benthic invertebrates. These areas constitute the so-called "patch reefs" of the eastern Gulf. The reefs are subject to wide fluctuations in temperature, turbidity, and other physicochemical parameters (Joyce and Williams, 1969), but how the extremes in these conditions affect the reef communities is poorly known.

Throughout winter, rough seas and cold weather accompany passage of frontal systems. During January and February of 1977 and 1978, water temperatures at shallow-water eastern Gulf reefs dropped and remained at 12-13 C for several weeks. We discuss in situ observations made at selected reefs during these periods of reduced water temperatures.

Materials and Methods—Scuba observations were conducted at selected reefs in 15–37 m depths off Tampa Bay, Florida during these cold-water periods (Fig. 1). Three 20 min dives were made at a reef in 18 m (2 dives) and 37 m (1 dive) on 6 and 9 February 1977, respectively. On 15 February 1978, a 30 min dive was made at each of 2 reefs in 15-16 m depths.

Surface and bottom water temperatures were taken with mercury thermometers carried by divers. When water clarity permitted, photographs were taken with a 35 mm Nikonos camera.

Results—Limited kills of the more sensitive tropical reef fishes [e.g., butterflyfishes (Chaetodontidae) and angelfishes (Pomacanthidae)] were observed at reefs in 18 and 37 m during February 1977. Other reef-fish species [e.g., the hogfish *Lachnolaimus maximus* (Labridae)] were lethargic and concealed within

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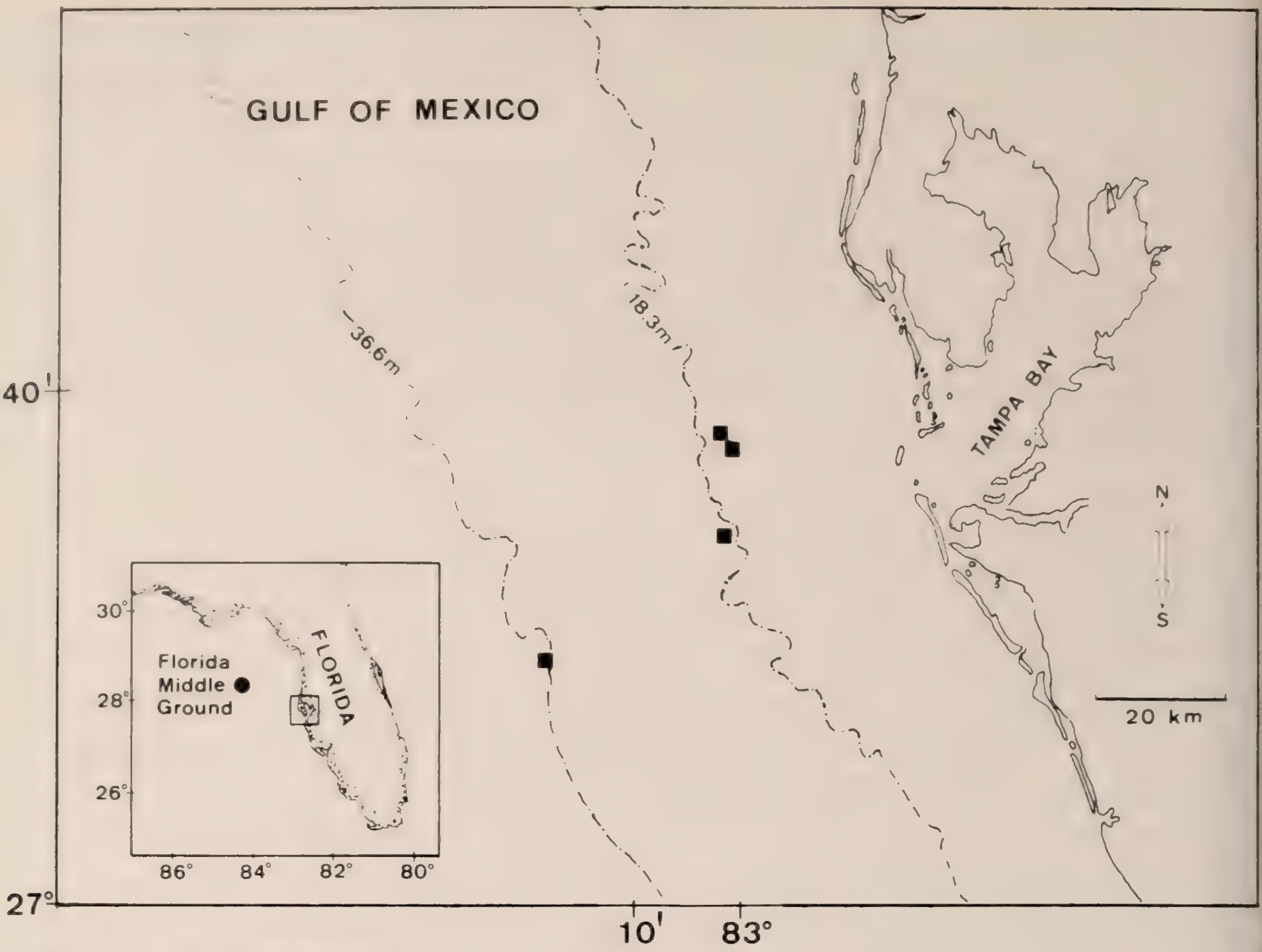

Fig. 1. Study reef locations.

reef recesses. Most gray snapper [*Lutjanus griseus* (Lutjanidae)] and hogfish had loose scales, eroded fin membranes, discoloration and open sores on the body (Fig. 2). These symptoms persisted several months after temperatures returned to their normal levels.

Cold water is apparently not the only adverse impact on reef communities. Rough seas generated by strong, sustained onshore winds (particularly from the W and NW) evidently create considerable bottom surge to depths of at least 18 m. On 15 February 1978, observations at 2 reefs (240-245°, 25 km off south St. Petersburg Beach) in 15-16 m depths indicated that this storm surge resulted in considerable mortality of the reef biota. Many of the gorgonian corals, *Muricea laxa* and *M. elongata* which are typically attached to the reef, were lying on sand peripheral to the reef. Several colonies (to 1 m dia) of the stony coral (*Stephanocoenia michelini*) were lying upside-down. Several large colonies (to 1 m dia and weighing 18 + kg) were overturned and their epifaunas were buried.

The fact that the overturned and unattached corals were alive and healthy suggested recent events. A few days earlier (13-14 February), a strong cold front accompanied by 35-58 km/hr SW and W winds passed through the Tampa Bay area. Local marine forecasts had called for a 1.7-2.4 m seas during frontal passage. This weather system was considered responsible for the damage to the reef biota.

Discussion—Cold-induced symptoms similar to those we observed in fishes have been reported. Thomson and Lehner (1976) reported ulcerated body sores on individuals of the damselfish *Abudefduf troschelii* (Pomacentridae) experi-

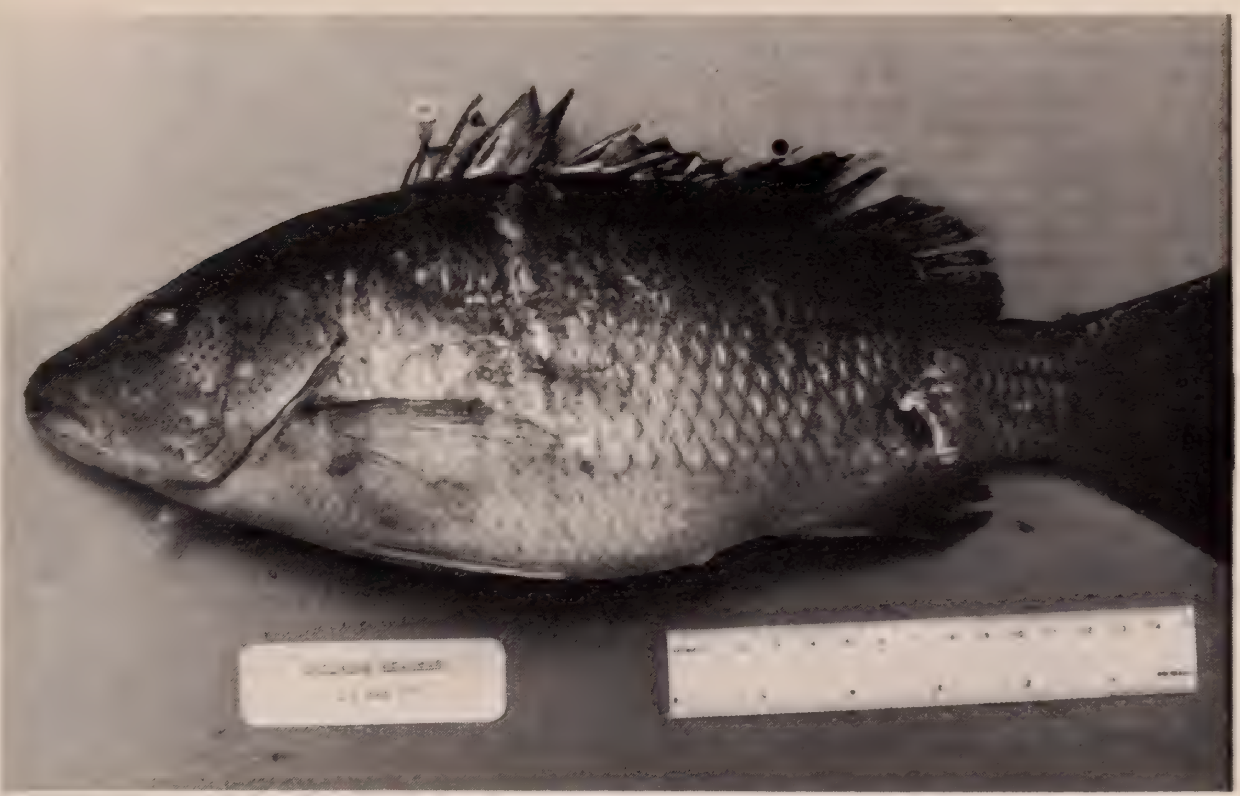

FIG. 2. A gray snapper (*Lutjanus griseus*) with ragged fins and body sores typical of individuals observed during the February 1977 cold-water period. The mark above the posterior portion of the anal fin is a spear wound.

mentally exposed to 9-12 C waters for 5 da. They observed that prior to death, many fishes could not maintain their equilibrium, possibly rendering them more vulnerable to physical damage during storms.

Commercial and recreational catches of groupers (Serranidae) and snappers (Lutjanidae) off west Florida were virtually non-existent during the 1977 and 1978 cold weather, indicating that reef-fish behavior was otherwise affected. Springer (1946) suggested that groupers and other benthic fish may occasionally be stunned or killed during cold-water upwellings off the Florida east coast.

Other investigators have described damage to shallow-water or emergent reefs due to heavy seas accompanying hurricanes (Springer and McErlean, 1962; Shinn, 1972; Stoddart, 1974). An unpublished cruise report (Florida State University System Institute of Oceanography, BLM Cruise No. 19, 2 September through 6 October 1975) described the impact of Hurricane Eloise on 20-25 m deep reefs at the Florida Middle Ground (Fig. 1). Scuba observers reported uprooted sponges and gorgonian corals, reduced visibility, and silt over many organisms. We know of no other reports regarding rough sea impact on deep-water reef communities.

Observations at eastern Gulf reefs indicate that storm-generated waves resulting in bottom surge can influence the stability of reef communities to depths of at least 18-20 m. We have no idea of what recovery time for this type of impact might be. Stoddart (1974) supposed that 20-25 yr might be required for rejuvenation of British Honduras reefs completely destroyed during a severe hurricane. However, Shinn (1972) reported rapid recovery of a few years of a Florida Keys reef where only moderate and localized hurricane damage had occurred.

Recovery of coral assemblages in the eastern Gulf of Mexico is undoubtedly slow because most species are living toward the northern limits of their distributions. Smith (1975) reported that corals colonized very slowly after a red tide defaunated nearshore Gulf of Mexico reefs. Seven years later, no conspicuous growth of scleractinian and alcyonarian corals had occurred (pers. obser. by G. Smith).

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Biological Sciences

AN ABSCISIC ACID–INDUCED SEPARATION LAYER IN *LEMNA MINOR* (L.)

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Abstract: *Axenic clones of* Lemna minor *(L.) were cultured on Hoagland's 1 medium with and without 0.2, 0.8, and 2.0 ug/ml abscisic acid (ABA). ABA-induced abscission occurs at all concentrations tested. In general, ABA treatment results in an inhibition of growth and an enhancement of senescence during the first 20% of the life span of the plant. The presence of an abscission zone in* Lemna *is demonstrated for the first time, and the role of ABA as an inducer of abscission in an intact plant system is clearly shown.*°

The mode of action of abscisic acid (ABA), its metabolism and its effect on the growth of *Lemna* have been studied by van Overbeek (1967, 1968). In con-

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junction with this work, the phenomenon of colonization in *Lemna* and its reversal by application of ABA has often been observed; however, a correlation between this and true abscission has not yet been established. Several papers have appeared describing the structural (Scott et al., 1967; Webster, 1968) and chemical (Addicott and Lyon, 1969; Dela Fuente and Leopold, 1968) characteristics of abscission. The acceleration of abscission by ethylene has been clearly shown (Morgan and Durham, 1972), and the induction of abscission in explants of cotton and several other species by ABA is well-documented (Borman, et al., 1967; Liu and Carns, 1961). ABA-induced abscission in an intact plant system, however, has not yet been described.

METHODS AND MATERIALS—An experiment was conducted such that any anatomical changes which occurred with the application of ABA could be monitored. Axenic clones of *Lemna minor* obtained from Johannes van Overbeek were grown at 24° C under GE 40-watt cool white fluorescent tubes (5400 lux, 24-hr photo-period). Hoagland's I solution (Hoagland and Arnon, 1950) was utilized both with and without 0.2, 0.8, and 2.0 ug/ml ABA. Plants were harvested daily for 7 da. A standard FAA Fixing technique (Johansen, 1940) was modified slightly (i.e., by decreasing the time in each solution) to accommodate the small size of the plants and to take into account the ease of penetration of the fixing and embedding solutions. A few crystals of eosin were added to 90% alcohol solution to stain the plants for better visibility during the fixing and embedding processes. Serial sections 7 um thick were prepared with a rotary microtome, cemented to slides using the Haupt's adhesive 4% formalin technique, and stained with a standard safranin-fast green series (Johansen, 1940). Sections were then mounted in Permount, dried, and photographed. A total of 371 plants containing 1291 fronds was examined. Altogether 110 abscission zones were noted. The average number of abscission zones per frond was counted and the percent abscission zones per frond determined. Analysis was by Chi-square, analysis of variance, and t-intervals.

RESULTS—Upon microscopic examination, in certain fronds, abscission zones were found at the base of the area described by Lawraleé (1943) as the 'pedicel.' Figure 1 details a median longitudinal section through the meristematic region of a *Lemna* plant. Data on percent abscission zones per plant and percent abscission zones per frond are in Table 1. There is a difference between the number of days plants are left in ABA solution and the percent abscission zones per plant ($F = 5.922$, $p < .05$). Also, there is a difference between concentration of ABA and percent abscission zones per plant. Chi-square indicates a difference between all levels of ABA treatment and controls when data are compared on a per-frond basis ($p < .05$). In addition, during the last 3 da of the experiment (Table 1) a general inhibition of growth, expressed as a decrease in the number of plants or the number of fronds, can be seen. By using the t-interval, it was determined that the greatest hormonal effect, on a per plant basis, was at the 2.0 ug/ml level of treatment ($1 - \alpha = 0.95$).

DISCUSSION—These experiments marked the first time that an abscission zone

TABLE 1. Appearance of abscission zones in ABA-treated and control plants.

Days	Concentration ABA (ug/ml)	Number of plants	Number of fronds	Number of abscission zones	% of abscission zones per plant	% of abscission zones per frond
0	0.0	7	17	0	0	0
	0.2	3	12	0	0	0
	0.8	8	18	0	0	0
	2.0	7	11	0	0	0
1	0.0	8	31	2	25	6
	0.2	9	22	0	0	0
	0.8	7	12	1	14	8
	2.0	6	14	2	33	8
2	0.0	15	48	0	0	0
	0.2	14	40	0	0	0
	0.8	13	26	0	0	0
	2.0	9	28	0	0	0
3	0.0	20	48	2	10	4
	0.2	12	56	4	33	7
	0.8	15	36	9	40	25
	2.0	9	31	4	44	13
4	0.0	24	79	3	12	4
	0.2	22	83	3	13	4
	0.8	13	45	3	23	7
	2.0	9	30	4	33	13
5	0.0	23	79	0	0	0
	0.2	21	84	9	33	11
	0.8	15	71	8	33	11
	2.0	12	43	13	66	30
6	0.0	22	76	3	13	4
	0.2	22	89	18	54	20
	0.8	14	58	13	50	22

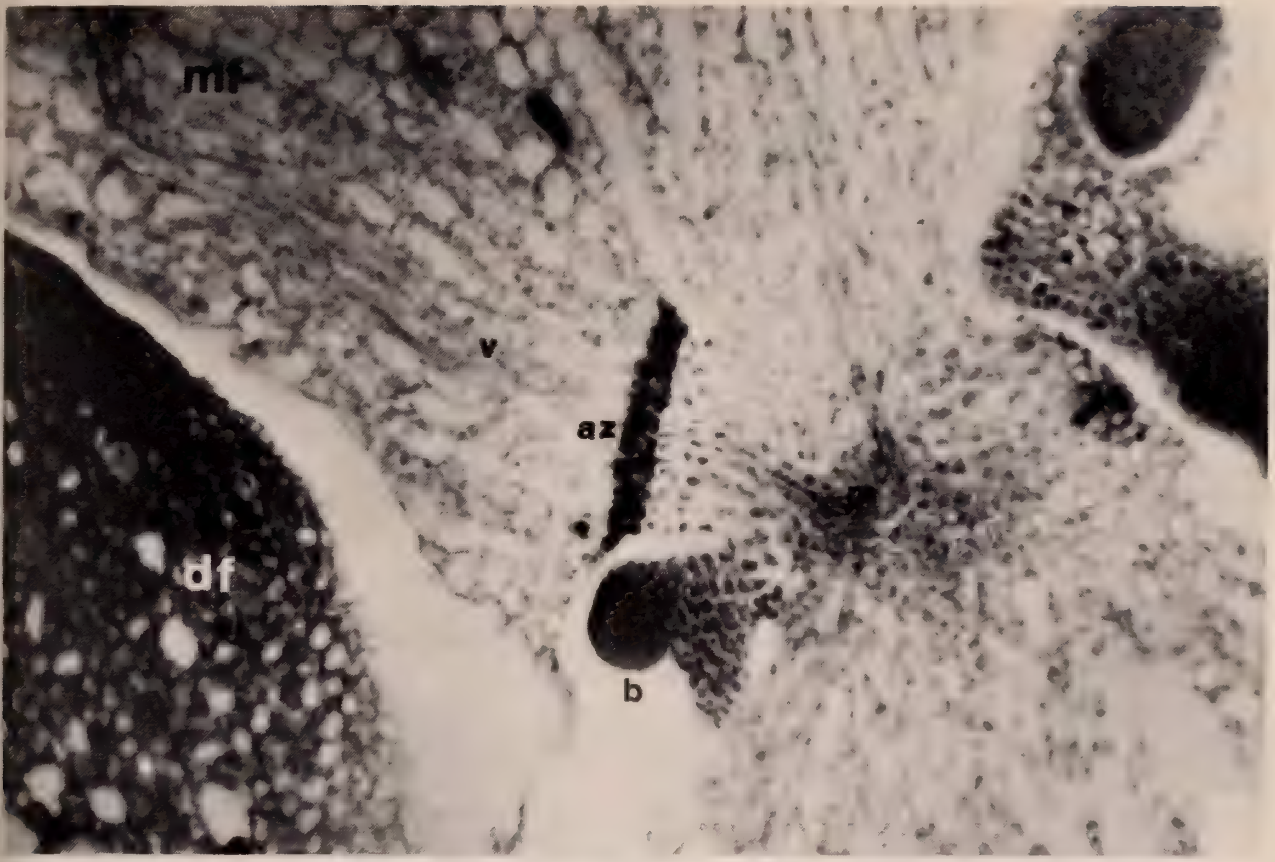

FIG. 1. Longitudinal median section through the meristematic region of *Lemna minor*. Meristem m), abscission zone (az), buds (b), mother frond (mf), daughter frond (df) vascular strand (v).

has been demonstrated in *Lemna*. Because the life span of a *Lemna minor* plant under these experimental conditions is 28-30 da (van Overbeek et al., 1968; Schwebel, 1973), and the presence of an abscission zone has long been considered an indication of the onset of senescence in a leaf, the effects demonstrated here indicate an onset of senescence during the first 20% of the life span of the plant. In addition to promoting senescence, ABA has a growth-inhibition effect on *Lemna*, although it is uncertain whether this effect is cumulative in nature.

Applying ABA in varying concentrations to *Lemna* results in increased abscission. The role of ABA as an abscission-inducing hormone is clearly established. This is perhaps the most important aspect of this work. *Lemna* provided an elegant tool for this research because of its rapid uptake of ABA, the absence of metabolizing bacteria, and the general structural simplicity of the plant.

It is not clear whether any other plant growth substance (i.e., ethylene) are involved here. Such a possibility (that this is an ethylene-medicated response) certainly cannot be ruled out, and should be the subject of further experimentation. Obviously, much work remains to be done before the mechanism of ABA-induced abscission is elucidated.

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Biological Sciences

A SURVEY OF SUSPENSION–FEEDING ANIMALS

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Abstract: *About 40,000 living species of animals are suspension feeders, comprising 16% of all aquatic species. Of all species of suspension-feeding animals, 43% are likely to be fossilized as compared to only 8% of all species of living animals. Nearly half of all living colonial animals are suspension feeders.*[*]

Suspension–Feeding Animals feed on small to minute organic particles nd organisms suspended in water. These organisms include phytoplankton, such s diatoms; zooplankton, such as radiolarians; the larval stages of larger animals; nd small metazoan animals, such as copepods. Some suspension feeders are alled filter feeders because they have complex filtering or straining structures vhich eliminate all but the smallest organisms. Most of the feeding in these ani-nals is aided by creating currents through the body toward the mouth, com-nonly by the action of cilia or flagella, or by swimming or by some kind of pump-ng action. A good review of these mechanisms among various suspension-feeding nimals has been presented by J. A. C. Nicol (1960). Additional information on he number of suspension-feeding species was obtained from Barnes (1974).

Of the estimated 1,240,000 living species (D. Nicol, 1977), about one-fifth re aquatic (Thorson, 1957). This would mean there are about 248,000 living pecies of aquatic animals. How many of these aquatic animals are suspension eeders? With the present state of our knowledge of many species of aquatic ani-nals, the best that can be hoped for is a reasonably close approximation of the umber of suspension–feeding species. In Table 1, I list the 37 living animal phyla vith the estimated number of species in each. Of these 37 phyla, 16 apparently ack suspension feeders. This comprises approximately 43% of all of the animal hyla. Only the Nematoda and Platyhelminthes, of these 16 animal phyla, have a large number of species; the remaining 14 each have less than 1,000 livin species. At the other extreme, there are 9 phyla wherein all species are suspension feeders. This comprises 24% of the 37 animal phyla. Only the Porifera an Bryozoa could be considered large phyla amongst this group. The other 7 phyl are all small, each having fewer than 1,000 living species.

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The remaining 12 phyla (32% of the total) each have some suspension feeder amongst their living species, and herein lies the greatest difficulty in obtaining reasonably accurate approximation of the number of living animal species tha

TABLE 1. The extant animal phyla with the number of species and the number of suspensio feeding species in each.

Phyla	No. of Species	No. of Suspension-Feeding Species
1. Protozoa	35,000	2,500
2. Mesozoa	50	0
3. Monoblastozoa	1	0
4. Porifera	5,000	5,000
5. Coelenterata	10,000	500
6. Ctenophora	100	0
7. Platyhelminthes	13,000	0
8. Rhynchocoela	750	0
9. Acanthocephala	600	0
10. Gnathostomulida	90	0
11. Rotifera	1,500	600
12. Gastrotricha	350	350
13. Kinorhyncha	100	0
14. Priapuloidea	8	0
15. Nematoda	50,000	0
16. Gordiacea	230	0
17. Calyssozoa	60	60
18. Bryozoa	4,000	4,000
19. Phoronida	25	25
20. Brachiopoda	300	300
21. Mollusca	58,000	10,000
22. Sipunculoidea	300	30
23. Echiuroidea	150	60
24. Myzostomida	150	0
25. Annelida	9,300	1,200
26. Tardigrada	350	0
27. Pentastomida	70	0
28. Onychophora	75	0
29. Arthropoda	1,000,000	12,000
30. Chaetognatha	75	0
31. Pogonophora	100	100
32. Echinodermata	6,000	1,000
33. Pterobranchia	25	25
34. Enteropneusta	100	15
35. Tunicata	1,600	1,300
36. Cephalochordata	30	30
37. Vertebrata	41,700	1,000
Species Totals	1,239,219	40,095

are suspension feeders. Only 3 of these 12 animal phyla are small in number of species, and the Arthropoda, Mollusca, Vertebrata, and Protozoa are very large animal phyla. As shown in Table 1, I estimate there are approximately 12,000 species of suspension feeders amongst the Arthropoda, only about 1% of all arthropod species, and even this rather low figure may be too high. In the Arthropoda, suspension feeding is essentially confined to the Crustacea. Possibly 10,000 species of molluscs, or about 17% of all living species of this phylum, are suspension feeders. Most pelecypods are suspension feeders and some gastropods also feed in this manner. Among the Protozoa, many ciliates are suspension feeders. The crinoids are all suspension feeders, but some asteroids and holothuroids use this method of feeding to a certain extent. The total number of suspension-feeding species is 40,095, which is about 3% of all living animal species or about 16% of all aquatic species.

The relatively small number of living animals that are suspension feeders may surprise some paleontologists because so many fossil communities appear to be dominated by suspension-feeding invertebrates such as brachiopods and pelecypods (see Scott, 1976, for some examples). It is possible there was a higher percentage, if not number, of species of suspension feeders in the past, and this is most probable for the fossil communities of the Ordovician, Silurian, and Devonian Periods, when brachiopods, bryozoans, and stemmed echinoderms were so diverse.

There are several reasons for the seeming dominance of suspension feeders in fossil communities. The percentage of suspension-feeding species of living animals that have inorganic skeletons or shells is much higher than one would find in all living animal species, and thus there would be a much greater likelihood that these animals would be preserved as fossils. In Table 2, I estimate the number of species of living suspension-feeding animals that are likely to be fossilized. The percentage of living suspension-feeding animals that are likely to be fossilized is about 43% as compared to only 8% of all species of living animals (D. Nicol, 1977). Suspension-feeding animals are most common in shallow-water marine environments, which are the most likely to be represented in the fossil record. Most suspension-feeding species occur in large numbers of individuals because they are near the base of the food pyramid. Furthermore, because many suspension-feeding animals are of small body size, the individuals tend to be more numerous, a fact which increases the likelihood that some will be fossilized. However, some species of animals that are suspension feeders are very large (e.g., some whales and sharks). There are some other general characteristics of suspension-feeding species. One of these is that a large number of them are colonial animals. The estimated number of colonial animals that are also suspension feeders is 5,535; that is 14% of all suspension feeding animals are colonial as shown in Table 2. The estimated total number of living colonial animal species is 11,935 (D. Nicol, 1978), and about 46% are suspension feeders.

Most suspension-feeding species are benthic, including most or all of the Porifera, Bryozoa, Calyssozoa, Phoronida, Brachiopoda, Echinodermata, Mollusca, and all species of some other minor phyla. Many of these suspension

TABLE 2. The extant animal phyla having suspension-feeding species; the number of suspension-feeding species that are likely to be fossilized; and the number of suspension-feeding species that are colonial animals.

Phyla	No. of Suspension–Feeding Species	Species Likely to be Fossilized	Colonial Species
1. Protozoa	2,500	0	400
2. Porifera	5,000	1,500	0
3. Coelenterata	500	250	200
4. Rotifera	600	0	0
5. Gastrotricha	350	0	0
6. Calyssozoa	60	0	30
7. Bryozoa	4,000	3,000	4,000
8. Phoronida	25	0	0
9. Brachiopoda	300	300	0
10. Mollusca	10,000	9,000	0
11. Sipunculoidea	30	0	0
12. Echiuroidea	60	0	0
13. Annelida	1,200	300	0
14. Arthropoda	12,000	2,000	0
15. Pogonophora	100	0	0
16. Echinodermata	1,000	700	0
17. Pterobranchia	25	0	5
18. Enteropneusta	15	0	0
19. Tunicata	1,300	0	900
20. Cephalochordata	30	0	0
21. Vertebrata	1,000	400	0
Species Totals	40,095	17,450	5,535

feeders are sessile benthos and epifaunal, but some, like most pelecypods, are infaunal. Few species are nektonic or planktonic.

As J. A. C. Nicol (1960) points out, many larvae of aquatic animals are suspension feeders (e.g., the trochophore of annelids, the veliger of molluscs, and larvae of echinoderms and enteropneusts). Thus, a large number of aquatic animals are dependent on phytoplankton, zooplankton, and small animals floating or swimming in the water for their food during a part or all of their life history. This must have been true at least throughout the Phanerozoic and very probably during the late Precambrian. Many paleontologists contend that the first animals were tiny planktonic animals, and later became benthic and gradually increased in size (D. Nicol, 1966). These first tiny animals that lived in the seas during the late Precambrian were probably suspension feeders and may have resembled the modern ciliates as well as the larval stages of living metazoan animals. Suspension feeding in these primitive animals was probably aided by the action of cilia or possibly flagella.

Many other small animals that are not suspension feeders are dependent on phytoplankton (e.g., the Foraminiferida), which obtain their food using pseudopodia.

Lane (1978) discusses the rapid decline of acritarchs, a type of phytoplankton, during the Devonian and their near disappearance by Mississippian time

Their decline coincides with the decline in the Devonian, and extinction in the early Mississippian, of the graptolites. It is quite likely that the graptolites were suspension feeders. The individuals of the colony in graptolites are tiny (generally < 1 mm), and it is unlikely that they fed by any means other than suspension feeding. The common explanation of the decline and extinction of the graptolites was that the Devonian jawed fishes may have eaten graptolite colonies. There were also other groups of marine suspension-feeding invertebrates that became extinct during or at the end of the Devonian (e.g., the Rhombifera, Diploporita, Cyclocystoidea, and Ophiocystoidea). Possibly the Carpoidea were suspension feeders; they also disappeared in the Devonian. Most of these classes of primitive echinoderms were not common nor diverse. The first real decline in diversity of the brachiopods occurred during and at the end of the Devonian, and several families of pelecypods disappeared at about this same time.

Thayer (1979) suggests that the decline and extinction of many of the suspension feeders living on soft sediments during the early Paleozoic was caused by the rise of deposit feeders. The deposit feeders disturbed the sediments and thus prevented the suspension feeders from living on soft substrates.

In summation: there was a considerable amount of decline and extinction of marine suspension-feeding invertebrates during and at the end of the Devonian and continuing into the early Mississippian. This coincides with the rapid decline of the acritarchs. However, there was an expansion and replacement by other suspension-feeding marine invertebrates during the Mississippian that offset the decline and extinction of the more primitive groups at the end of the Devonian. A good example of expansion in the Mississippian of a suspension–feeding group of animals was the crinoids.

Tappan and Loeblich (1971) have discussed the relationship between the decline of phytoplankton and the major periods of extinction of the higher taxa of animals. Phytoplankters were scarce during the Permian, having dwindled since the Devonian. Many suspension-feeding animals were greatly affected during and at the end of the Permian, and this was the time of greatest extinction of marine animals. Among the suspension–feeding animals that became extinct were 2 major groups of bryozoans, all of the blastoids, most of the crinoids, and many families and superfamilies of brachiopods (Williams, 1965). The Rostroconchia, now considered to be a separate class of molluscs, were probably suspension feeders; they became extinct during the Permian. Even those animals that depended on tiny plants and animals for food, such as the fusulinids, did not survive the crisis at the end of the Permian. The amount of phytoplankton continued low throughout the Triassic and some additional extinctions occurred in an impoverished marine fauna. Some families and superfamilies of brachiopods became extinct in the Triassic. The conulariids disappeared during the Triassic, and it is quite possible they were suspension feeders. Even more significant was the extinction of the conodonts in the Triassic. It is likely that they were suspension feeders.

Phytoplankton became more numerous in the Jurassic and throughout the Cretaceous until the end of the latter period. At the end of the Cretaceous, phytoplankton again declined, causing the extinction of several groups of pelecypods as well as most of the planktonic Foraminiferida and some large benthic Foraminiferida. Another reduction of the phytoplankton supply, although less severe than at the end of the Cretaceous, occurred at the end of the Oligocene Epoch and had an adverse effect on those animals dependent on phytoplankton for food.

Tappan and Loeblich (1971) also point out that the reduction of phytoplankton in the seas would increase the dissolved carbon dioxide in the water, thus lowering the pH level. This would affect reef-forming organisms and may explain the extinction of the rugose corals at the end of the Permian and the drastic reduction of the tabulate corals at the same time. It also could have had its adverse effects on the bryozoans mentioned earlier. The lowering of the pH that also likely occurred at the end of the Cretaceous may have been just as important for the extinction of the rudist pelecypods as the reduction of their supply of food. It should also be mentioned that some families of the modern scleractinian corals disappeared at the end of the Cretaceous, and, again, the cause may have been the lowering of the pH.

There appears to be no doubt that the major periods of extinction of marine animals, particularly the suspension–feeding species, is directly related to the periods of great decline in the production of phytoplankton, which is so necessary for the livelihood of all of the animals living in the seas.

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Environmental Sciences

EFFECTS OF FIRE ON A KISSIMMEE RIVER MARSH

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Abstract: *A marsh composed primarily of maidencane* (Panicum hemitomon) *and pickerelweed* Pontederia lanceolata) *in the Kissimmee River floodplain was studied to determine the effects of fire on primary and secondary productivity. A 100 square meter plot was burned in June 1974 and a imilar unburned plot was the control. Primary and secondary productivity were sampled bimonthly from August 1974 thru February 1975. An almost complete recovery of the vegetation in the burned plot occurred within 6 mo. Total numbers of both animal species and individuals were significantly greater in the burned plot than in the control plot. Burning is a useful management tool to increase econdary productivity in the Kissimmee River marshes.*[*]

Wetland Plant Communities play an important role in aquatic ecosystems. Marsh vegetation of the Kissimmee River floodplain provides food and protection or populations of macroinvertebrates and small forage fishes that form the basis of the aquatic food chain (Milleson, 1976). Effects of fire on animal populations have been described to some extent, primarily with regard to terrestrial organsms such as birds (Loveless, 1959; Hofstetter and Parsons, 1973; Emlen, 1970) and insects (Metz and Farrier, 1973, McCoy, 1973). The effects of fire on aquatic animal populations have not been well documented (Vogl, 1973).

The effects of fire on upland and some wetland vegetation in south Florida have been described in some detail (Davis, 1943; Egler, 1952; Loveless, 1959; Craighead, 1971; Hofstetter and Parsons, 1973). However, limited research has been conducted in sawgrass (Forthman, 1973; Steward and Ornes, 1975; Hoftetter and Parsons, 1975) and maidencane marsh (Vogl, 1973) communities.

Our study was conducted in Pool C of the Kissimmee River basin approximately 42 km north of Lake Okeechobee (Fig. 1). Marshlands of the Kissimmee River floodplain have been altered by construction of the C-38 canal and 5 water mpoundments or pools (Dineen, et al., 1974).

Constant water levels have selected for a restricted number of species that olerate continuous inundation at the lower end of each pool and have created dry grasslands at the upper end of each pool. Water levels in the Kissimmee River mpoundments can be regulated to flood or drain the marshland. The water level in Pool C was stabilized at 10.36 m above mean sea level (msl) from 1968 to 1973.

The study area is approximately 200 ha or 25% of the marsh in Pool C. The vegetative cover consists primarily of maidencane (*Panicum hemitomon*) and pickerelweed (*Pontederia lanceolata*). In 1973, a program was initiated by the

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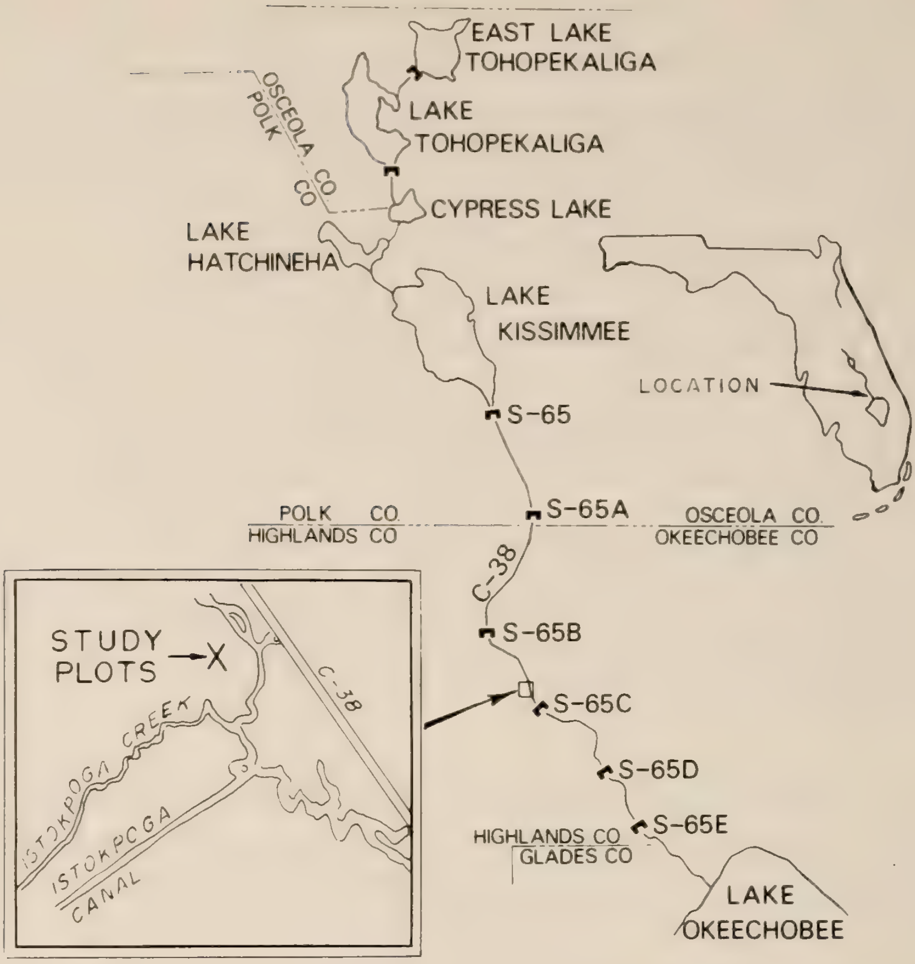

Fig. 1. Location of study plots in Pool C of the Kissimmee River floodplain, Florida.

South Florida Water Management District (SFWMD) to manipulate water levels and seasonally dry out the marshes in Pool C (see Fig. 2). In the current study, a portion of the 200 ha maidencane marsh was burned during a dry period and the newly burned marsh was subsequently reflooded. Samples were collected to determine the effects of fire and reflooding on vegetation, macroinvertebrates and small fishes in the marsh.

Materials and Methods—Water stages in Pool C were determined from records at water control structure S-65C of the SFWMD. Water depths in the wet prairie ranged from 12-22 cm when the stage in Pool C was 10.36 m above msl. The water table was below ground level for almost 2 mo prior to burning and the marsh was reflooded within 3 wk after burning (Fig. 2). The water level in Pool C was abruptly lowered and kept low during 12 da in October 1974 to facilitate repairs of a weir.

Test and control plots were selected within a representative area of the marsh and approximately 300 m from the nearest river oxbow. Each plot was 10 m on a side. Because the marsh contained a great deal of dead and dry plant material a 3 m wide fire break was cut around the margin of the experimental plot. On 11 June 1974 the plot was burned.

Biological samples were taken every other month from August thru February Plants and animals were collected from 5 replicate quadrats within each plot An additional sample of animals only was taken on October 23, 1974, immedi-

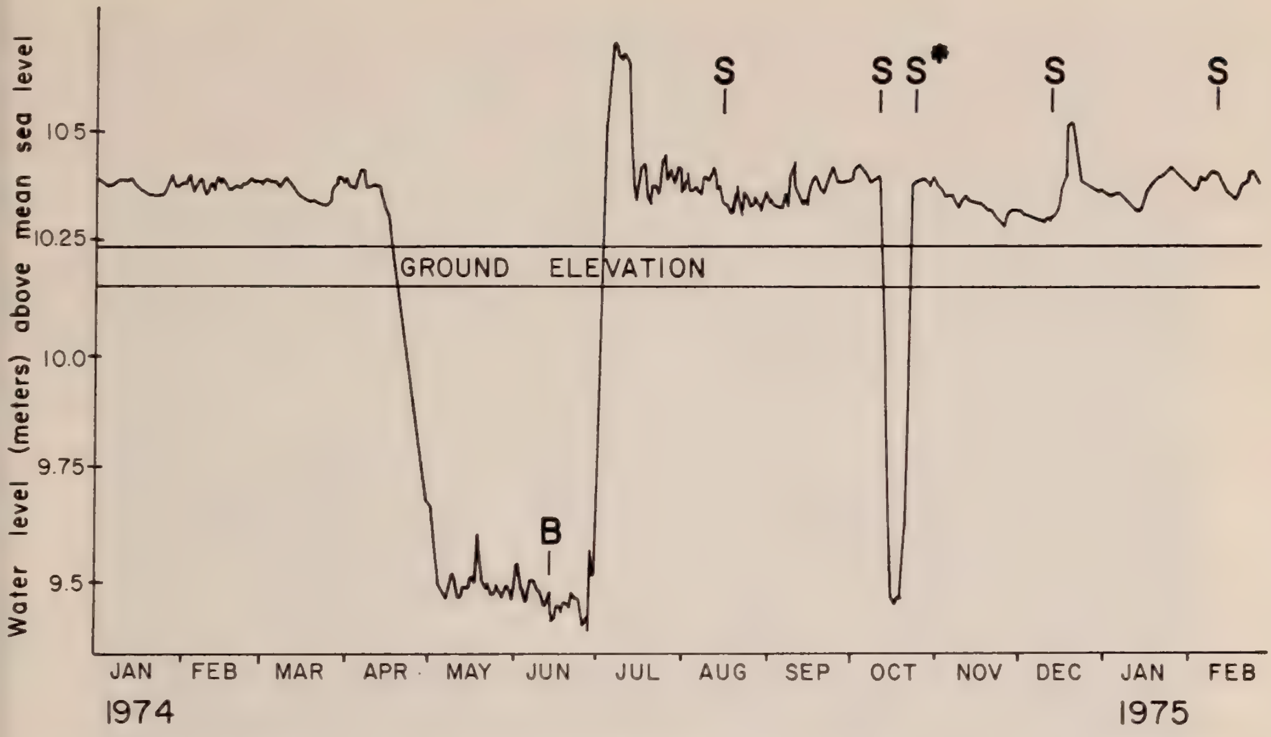

Fig. 2. Water stage records in meters above mean sea level for Pool C of the Kissimmee River from January 1974 thru February 1975. Ground elevation of the test plots was between 10.14 and 10.23 m. One plot was burned (B) and samples (S) were taken of the burned plot and the control plot at the times indicated. On October 23, 1974 (*), only animal samples were collected.

ately after the drawdown (see Fig. 2). Samples were taken by a unit-area sampling technique (Welch, 1948). Replicate samples were equally spaced along a line that was drawn across the plot. On each sampling date a different line was used that was parallel to the original line. No point in the plot was sampled more than once.

The "sampler" consisted of a galvanized steel washtub that had the bottom removed. The washtub was placed firmly against the soil and enclosed an area of 0.2 square meters. Plants within the tub were removed at ground level. Invertebrates and small fishes were scooped from the tub with a 3 mm mesh net. Scooping was continued for 3 successive times after there was no visible detritus or organisms in the net.

Living vegetation from each sample was identified to species. The wet weight and the number of stems or petioles of each species were determined within 6 hr after collection. Plant biomass did not include the periphyton and *Utricularia sp.* which were present in the burned plot but were difficult to handle and weigh.

Faunal samples were preserved in 10% formalin as they were collected. Edward Terczak, biologist at the SFWMD, identified all invertebrates. Many of the organisms, especially insects, were present as immature stages and were not identified to species.

Animal species diversity ($\overline{H}$) (Shannon and Weaver, 1963) was calculated as $\overline{H} = -\Sigma(n_i/N)\log_2(n_i/N)$ where n_i is the number of individuals of a given species and N is the total number of organisms in the sample. Diversity was calculated on the basis of the total number of species and individuals collected from each plot at each sampling date.

RESULTS—*Panicum hemitomon* and *Pontederia lanceolata* were the most common plants in the 200 ha marsh. The following species were infrequently observed: *Sagittaria lancifolia, Cyperus haspan, Centella asiatica, Eleocharis acicularis, Hibiscus grandiflora, Habenaria repens, Hydrochloa carolinensis, Leersia hexandra, Ludwigia repens, Panicum paludivagum, Polygonum sp., Proserpinaca palustris*, and *Cyperus sp.*

The burned plot showed significant regrowth of vegetation within 3 wk after burning (Fig. 3). By August, the control plot contained 2340 g/m^2 of plants, (above-ground fresh weight of living material) including 1440 g of maidencane and 880 g of pickerelweed (see Table 1). The burned plot contained 1360 g/m^2 of vegetation, with 620 g of maidencane, 308 g of pickerelweed and 439 g of arrowhead.

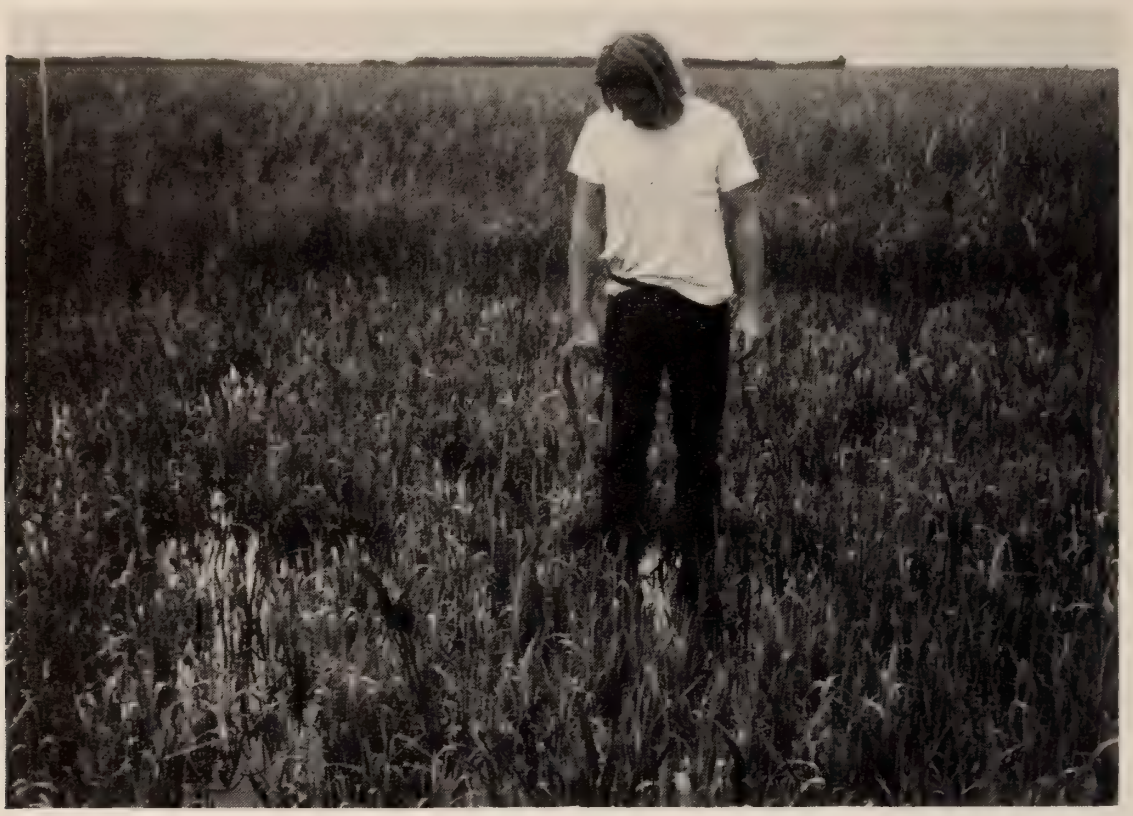

Fig. 3. The burned plot, 3 wk after burning, shows significant regrowth of vegetation from rhizomes.

Total plant biomass in the October samples had declined to 2080 g/m^2 in the control plot. These samples contained 1050 g of maidencane and 1010 g of pickerelweed. The biomass of the burned plot had increased to 1610 g/m^2 and included 798 g of maidencane and 812 g of pickerelweed.

By December (Fig. 4), total plant biomass had declined to 1100 g in the control plot, including 711 of maidencane and 358 g of pickerelweed. The burned plot contained 600 g of maidencane and 459 g of pickerelweed for a total of 1060 g.

The February sample from the control plot contained 1400 g/m^2 of vegetation, with 712 g of maidencane and 685 g of pickerelweed. The burned plot contained 964 g of plant material, including 731 g of maidencane and 233 g of pickerelweed.

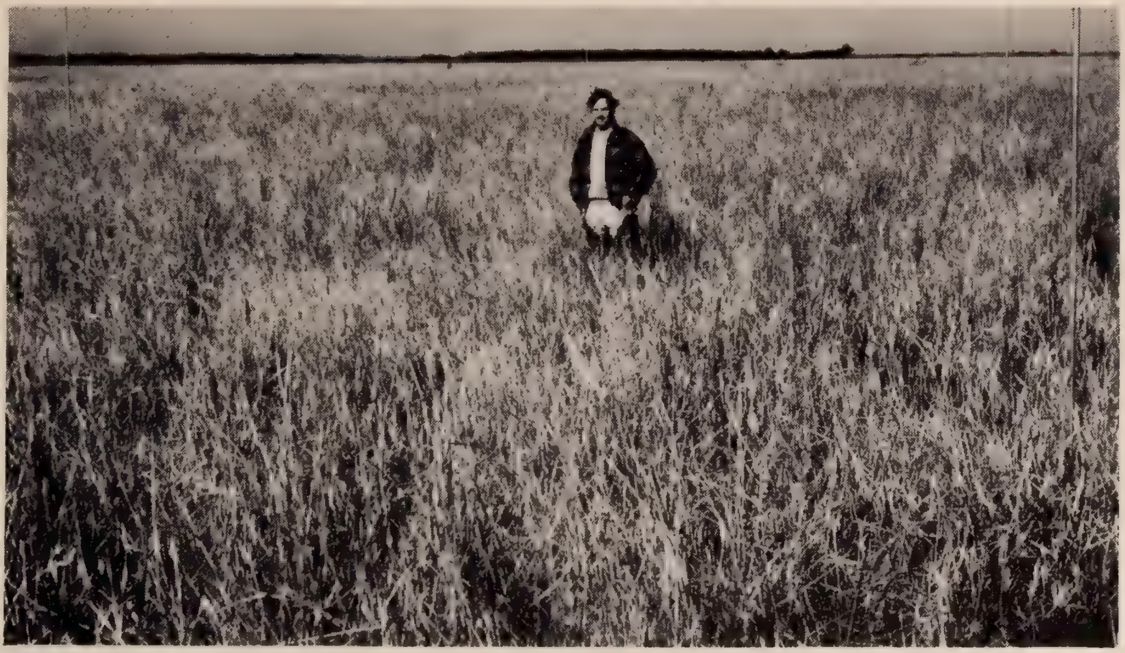

Fig. 4. The burned plot, 6 mo after burning, is indistinguishable from the surrounding unburned area.

On one occasion samples from the burned plot contained S. *lancifolia*. Samples from the control plot included small amounts of *Leersia hexandra, Panicum paludivagum, Polygonum sp.*, and *Cyperus sp.*

During the study 1 species of amphibian, 5 species of fish, and 88 species of invertebrates were collected in the samples (Table 2). Decapod crustaceans were collected only from the burned plot. Isopods and amphipods were more numerous in the burned plot than in the control plot. Insect populations in the control plot were considerably different from those in the burned plot. Samples from the burned plot contained 7 species of Odonata, 3 species of Hemiptera, 10 species of Diptera, and 30 species of Coleoptera. Samples from the control plot contained 1 species of Odonata, 6 species of Hemiptera, 3 species of Diptera, and 18 species of Coleoptera.

Five species of fish and 2 species of decapod crustaceans were collected from the plots on 8 October 1974. However, the sharp decline in water levels that occurred in late October caused an immediate loss of both the fish and decapod populations. Fish were again collected from the plots in December 1974 and one shrimp was collected from the burned plot in February 1975.

Species diversity in the two plots ranged from 2.09-4.31 (Table 3). Average diversity of the burned plot was 3.02, while diversity of the control plot was 2.63. Numbers of individuals per square meter and species per square meter were significantly greater ($P < 0.05$) in the burned plot than in the control plot. The difference in diversity index was not significant. Increases in numbers of species and individuals of decapods, arthropods, and vertebrates were not statistically significant, whereas increases in insects and other invertebrates were significant ($P < 0.05$).

DISCUSSION—The maidencane marsh community in Pool C of the Kissimmee River floodplain contrasts sharply with wet prairies in the northern Ever-

Table 1. Biomass (g) of plants collected from the burned plot and the control plot. Each replicate (Rep) represents a single 0.2m^2 vegetation sample.

		Burned Plot				Control Plot			
Date	Rep. No.	*Panicum hemitomon*	*Pontederia lanceolata*	Other	Total	*Panicum hemitomon*	*Pontederia lanceolata*	Other	Total
	1	298.4	64.4	0.6[a]	363.4	68.0	81.3	68.6[e]	217.9
	2	165.2	253.3	22.5[a]	441.0	185.8	214.5	--	400.3
8-13-74	3	471.0	162.3	--	633.3	156.4	--	--	156.4
	4	194.4	102.0	--	296.4	106.5	11.8	--	118.3
	5	313.9	295.8	0.5[b]	610.2	100.8	--	370.0[e]	470.8
	(Mean (SD)	288.6(120.5)	175.6(98.0)	--	468.9(148.9)	123.5(47.0)	61.5(92.0)	--	272.7(154.8)
	Total (g/m^2)	1442.9	877.8	23.6	2344.3	617.5	307.6	438.6	1363.7
	1	79.8	267.3	24.1[a,c]	371.2	156.7	270.5	--	427.2
	2	237.5	414.7	7.8[a]	660.0	191.5	80.4	--	271.9
10-8-74	3	264.4	155.5	--	419.9	168.2	210.0	--	378.2
	4	280.3	--	--	280.3	195.1	52.8	--	247.9
	5	183.4	170.0	--	353.4	87.0	198.1	--	285.1
	Mean (SD)	209.1(81.1)	201.5(152.8)	--	417.0(144.8)	159.7(43.7)	162.4(92.1)	--	322.0(76.7)
	Total (g/m^2)	1045.4	1007.5	31.9	2084.8	798.5	811.8	--	1610.3

12-10-74	1	125.1	69.8	9.1^{a,d}	204.0	62.6	165.3	--	227.9
	2	154.4	33.2	15.1^{a,e}	202.7	163.4	100.8	--	264.2
	3	191.2	60.8	9.4^{a,e}	261.4	94.6	71.5	--	166.1
	4	69.8	116.8	--	186.6	130.4	66.0	--	196.4
	5	170.2	77.0	--	247.2	148.5	55.5	--	204.0
	Mean (SD)	142.1(47.1)	71.5(30.2)	--	220.4(32.1)	119.9(41.0)	91.8(44.4)	--	211.7(36.7)
	Total (g/m^2)	710.7	357.6	33.6	1101.9	599.5	459.1	--	1058.6
2-12-75	1	84.2	242.5	1.5^a	328.2	134.3	59.2	--	193.5
	2	104.0	73.8	3.0^a	180.8	237.6	51.6	--	289.2
	3	170.3	65.8	2.1^a	238.2	154.4	14.7	--	169.1
	4	195.8	215.7	1.4^b	412.9	84.1	102.2	--	186.3
	5	157.2	87.4	--	244.6	121.0	5.0	--	126.0
	Mean (SD)	142.3(46.7)	137.0(84.9)	--	280.9(90.6)	146.3(57.1)	46.5(38.8)	--	192.8(59.9)
	Total (g/m^2)	711.5	685.2	8.0	1404.7	731.4	232.7	--	964.1

[a] *Leersia hexandra.*
[b] *Polygonum sp.*
[c] *Panicum paludivagum.*
[d] *Cyperus sp.*
[e] *Sagittaria lancifolia.*

glades, which generally have very sparse emergent vegetation and do not contain sufficient fuel to burn (Goodrick, 1974). The 200 ha wet prairie contained a dense growth of maidencane and pickerelweed, a considerable amount of dead plant material and several centimeters of organic detritus above inorganic silica sand soil, and was not known to have burned for at least 6 yr.

Table 2. Density of organisms (number/m²) that was collected from the burned plot and from the control plot at each sampling date.

	Control Plot					Burned Plot				
	8-13-74	10-8-74	10-23-74	12-10-74	2-12-75	8-13-74	10-8-74	10-23-74	12-10-74	2-12-75
Amphibia										
Diemictylus sp.					7					2
Pisces										
Heterandria formosa		2		3	1		7		9	2
Gambusia affinis		6					7		3	2
Fundulus chrysotus						1				
Jordanella floridae							2			
Elassoma evergladei					1					
Decapoda										
Procambarus fallax						1	7			
Palaemonetes paludosus						2	2			1
Amphipoda										
Hyalella aztecus	43		24	70	94	15		173	289	147
Isopoda										
Asellus militaris	6	4	1	35	159	11	15	29	109	251
Odonata (naiads)										
Anax longipes							1			
Coryphaeschna ingens								2		
Lepthemis simplicicollis							1	2	1	
Pachydiplax longipennis		1	1	8	11		8		22	45
Tramea abdominalis								1		
Ischnura posita										1
Enallagma traviatum										4
Ephemeroptera (larvae)										
Callibaetis floridanus						2			2	3
Caenis diminuta							1		2	1
Hemiptera										
Belostoma sp.		1	1	3	4			2	3	
Benacus griseus										1
Pelocoris femoratus								1		
Pelocoris sp.		1					1	1	3	2
Buenoa sp.	1	2								
Macrovelia sp.			4							
Saldoida sp.	1									
Brochymena sp.					5					
Diptera (larvae)										
Bezzia sp.							1			1
Chironomus crassicaudatus			1			5	13	2	3	55
Ablabesmyia cinctipes							8	2	1	1
Polypedilum sp.			1				3			2
Procladius sp.										6
Tanytarsus sp.										2
Dicrotendipes modestus										1
Chaoborus punctipennis										1
Chrysops sp.									6	2
Tabanus sp.						1				
Hexatoma sp.									4	

Limonia sp.		1	3	10				26	48	1
Coleoptera										
Donacia sp.				1						1
Agabus aeruginosus			1					1		
Agabus sp. (larva)	2									
Bidessus sp. (larva)										1
Celina angustata							1			3
Celina contiger								1		
Celina grossula		3	1		2	4	8	1	2	6
Celina slossoni	1	1			1	4	3	1	3	14
Copelatus glyphicus		1					3			
Cybister sp. (larva)	1									
Dytiscus sp. (larva)	1					1		1		
Hydaticus bimarginatus										2
Hydroporus sp. (larva)	1	1				8	1			
Hydrovatus compressus		1			2	1	1	2	1	
Pachydrus princeps	1									
Rantus calidus					2					
Thermonectus basillaris									3	3
Pelonomus sp. (larva)		1							1	
Stenelmis sp. (larva)		1								
Gyrinus sp. (larva)										1
Gyrinus woodruffi										1
Berosus striatus									8	
Peltodytes sp. (larva)					1					14
Derallus altus	2				1		1			
Enochrus blatchleyi								2	1	
Enochrus cinctus								1		
Enochrus ochraceus									1	
Helochares sp. (larva)					1					
Paracymus lodingi								1		
Tropisternus blatchleyi										3
Tropisternus nimbatus									1	2
Neohydrophilus castus									1	
Colpius inflatus							1	1		
Hydrocanthus oblongus			1			8	15	5	2	
Suphisellus floridanus							1		1	
Suphisellus punctipennis							1			
Hymenoptera										
Cryptinae	2	4	2				2			
Lepidoptera										
Nymphula sp. (larva)				5	2			1	2	1
Collembola										
Isotomurus palustris			1							
Tricoptera										
Polycentropus sp.										1
Oecetis sp.										1
Orthoptera										
Tettigidea sp.					7					
Blatta orientalis				1	1					
Annelida										
Hirudinea	1		2	3	2		7	2	3	6
Tubifex tubifex		1	4	4	2	8	4	6	6	4
Ostracoda										
Candona sp.	12					26	1			
Gastropoda										
Viviparus georgianus						2				
Pomacea paludosa								1		
Physa pomilia				1			1		1	1

The prescribed burn consumed most of the vegetation and all dead plant material above ground. Due to dampness much of the soil litter, plant roots, and rhizomes were not burned.

Previous studies in the Kissimmee River floodplain indicated that when over-

Table 3. Animal species composition and diversity in burned and control plots within a Kissimmee River marsh, 1974-1975.

Date	Plot Type	Insects		Decapods		Other Arthropods		Other Invertebrates		Vertebrates		Diversity Index (H)	Total I/M^2	Total S/M^2
		S[a]	I[b]	S	I	S	I	S	I	S	I			
8/13	burned	9	34	2	3	3	52	2	10	1	1	3.3994	100	17
	control	10	13	0	0	3	61	1	1	0	0	2.2576	75	14
10/8	burned	21	75	2	9	2	16	3	12	3	16	4.3115	128	31
	control	13	19	0	0	1	4	1	1	2	8	3.7421	32	17
10/23	burned	21	57	0	0	2	202	3	9	0	0	2.1245	268	26
	control	11	17	0	0	2	25	2	6	0	0	2.770	48	15
12/10	burned	24	122	0	0	2	398	3	10	2	12	2.4379	542	31
	control	6	28	0	0	2	105	3	8	1	3	2.3113	144	12
2/12	burned	32	183	1	1	2	398	3	11	3	6	2.8319	599	41
	control	13	40	0	0	2	253	2	4	3	9	2.0880	306	20
Mean burned		21.4	94.2	1.0	2.6	2.2	213.2	2.8	10.4	1.8	7.0	3.02	327.4	29.2
Mean control		10.6	23.4	0	0	2.0	89.6	1.8	4.0	1.2	4.0	2.63	121.0	15.6
t Statistic		2.96°	3.27°	2.24	1.54	1.0	2.22	3.16°	3.72°	2.45	1.28	1.27	3.09°	4.27°°

[a] S = number of species.
[b] I = number of individuals.
° = significant at 95% confidence level, °° = significant at 99% confidence level.

lying vegetation, detritus and plant rhizomes were removed by fire or mechanical means, previously dormant and windblown seeds may germinate to form an entirely different plant community. Thus, when a dense mat of *Scirpus cubensis* and *Eichhornia crasspies* in Pool B was burned, the replacement vegetation consisted of a more diverse community of emergent aquatic plants (Goodrick and Milleson, 1974).

In the current study, the 2 dominant plant species were maidencane and pickerelweed. The burned plot had significant plant regrowth within 3 wk and had almost the same total biomass as the control plot within 6 mo after burning. These species are tolerant of fire and recover rapidly by regrowth from rhizomes. Therefore, the fire in Pool C caused no significant change in the plant species composition. Loveless (1959) reported that maidencane had a widespread distribution in the Everglades because of its "ability to withstand both widely fluctuating water levels and repeated burning." Vogl (1973) found that significant regrowth of maidencane occurred within 1 mo after burning.

Vogl (1973) studied the effects of burning on the marshes of a north Florida pond. Areas that were burned showed rapid regrowth of vegetation and had significantly higher biomass of vegetation within 4 mo than areas that were not burned. Periodic burning of marsh vegetation removes accumulated dead plants and detritus (Forthman, 1973), increases the availability of soluble nutrients (Ahlgren and Ahlgren, 1960; Forthman, 1973; Steward and Ornes, 1975) and increases the sunlight penetration to the soil surface (Hofstetter, 1974). When these areas are reflooded soon after burning, the availability of sunlight and dissolved nutrients may stimulate extensive growth of periphyton, submergent and emergent plants.

Burning is used in range management for certain species of wildlife, especially game birds (Linde, 1969). Birds usually are neither injured nor frightened by fires and are often attracted to smoke and fire (Vogl, 1973). Both Emlen (1970) and Hofstetter (1974) indicate that burning has no significant effect on bird concentrations in Florida pineland communities but may induce changes in bird species composition.

In terrestrial communities, Metz and Farrier (1973) have shown that burning reduces the soil mesofauna. Burning also increases the nutritional value of forage plants (Dewitt and Derby, 1955). It is not known if these conditions occur after wetlands are burned.

Research dealing with effects of fires on plants and animals in wetlands is acking (Vogl, 1973). Our study may be the first controlled experiment to assess he effects of burning of marshlands on repopulation of these areas by aquatic animals. Burning of marsh vegetation in a 100 m^2 plot and subsequent reflooding ed to a significant increase in secondary productivity within the plot. Increased econdary productivity furnishes additional food for wading birds and for larger ishes when the water levels are seasonally fluctuated (Milleson, 1976).

Decapods, amphipods, and isopods were present in greater numbers in the burned plot than in the control plot. These crustaceans may have increased in number in response to periphyton, algae, and open water that were present only in the burned plot. Water levels in the marsh were approximately 0.6 m below ground level for 6 wk before the plot was burned. Crayfish and insects may survive such a drawdown but it is not likely that live-bearing fishes such as *Gambusia affinis* and *Heterandria formosa* would have survived this exposure. Therefore, much of the increase in aquatic animals in the burned plot may have been due to emigration from adjacent unburned marshland and river.

When water levels in Pool C were again lowered in October 1974, there was an immediate loss of fishes and decapods. Changes in populations of other invertebrates were less severe. Fishes again invaded the plots during the 2 mo prior to December 1974. Decapod crustaceans may have survived the October drawdown but were not collected from the plots until February 1975.

CONCLUSIONS:—1. This maidencane and pickerelweed marshland in the Kissimmee River floodplain is fire tolerant. Total plant biomass of the burned plot was nearly the same as the biomass of the control plot within 6 mo after burning

2. Burning did not noticeably alter the plant species composition. Regrowth was primarily from rhizomes of existing plants rather than growth from seeds. Therefore, there was no apparent change in species composition.

3. The burned plot contained no *Panicum paludivagum*, *Polygonum sp.*, o *Leersia hexandra*, but did contain *Utricularia sp.* and periphyton that were no found in the control plot.

4. The burned plot had 7 species of Odonata (immature), 10 species of Diptera, and 30 species of Coleoptera, whereas the control plot had 1 species of Odonata, 3 species of Diptera, and 18 species of Coleoptera.

5. The total numbers of both animal species and individuals were significantly greater in the burned plot than in the control plot. Species diversity wa not significantly greater in the burned plot than in the control plot.

6. A sharp reduction in water level, in October, caused a decline in populations of fishes and decapod crustaceans. Fishes emigrated into the plots withi 2 mo after the prairie was flooded.

7. Prescribed burning of marshlands may be an effective management technique, when used in conjunction with manipulation of water levels, for the production of macroinvertebrates and small fishes as food for wading birds and large fishes.

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Biological Sciences

CITRUS PESTS IN AN URBAN ENVIRONMENT[1]

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ABSTRACT: *We studied the effect of a postbloom malathion:copper spray and a summer oil methidathion, benomyl and chlorobenzilate spray on the populations of important commercia citrus pests found on urban citrus trees. The spray program lowered the percentage of leaves infested with citrus rust mite,* Phyllocoptruta oleivora *(Ashm.), and significantly lowered the tota number of scale insects present from June-November on foliage of treated trees. Overall, the population dynamics of pests on treated and untreated trees proceeded as if these pests were in a commercial grove, rather than on urban citrus trees. Major differences, however, existed in the statu of the various phytophagous species in the urban versus the grove environment. Because tree appearance is of paramount importance to urban homeowners, the important pests are those that impai the tree's aesthetic beauty rather than those that reduce fruit yield or quality. The important urba pests are aphids, whitefly adults and sooty mold, while the major pests of commercial citrus—citru rust mites and greasy spot disease* Mycosphaerella citri *Whiteside—are considered of little importance by the homeowner.*[*]

DATA ARE AVAILABLE on population trends, impact of biological contro agents, influence of weather, and pesticide effects for pests of commercial citru (Simanton, 1959; 1976). However aside from control measures, little is know about the pests of urban citrus trees. The importance of generating similar dat for citrus pests in the urban environs has been underscored by the discovery o the citrus blackfly (CBF), *Aleurocanthus woglumi* Ashby, in southeastern Florid in 1976. Citrus blackfly is currently found throughout the urban and semi-urba areas of Broward, Dade and Palm Beach counties and in isolated urban areas o another 5 counties. The effectiveness of a number of insecticides for CBF control has been tested on trees in the urban setting (Reinert, 1976). However, th compatibility of these compounds with current commercial citrus spray programs is unknown partly because baseline data on the population trends of majo citrus pests on urban trees are lacking. We examined population trends and relative importance of arthropod and disease pests of commercial citrus on urba trees under a commercial spray program. We limited our study to one seaso because the heavy media usage by the eradication program caused many homeowners to believe that their trees, if infested with CBF, would die. Thus, as th experiment proceeded more and more homeowners stopped cooperating an began to apply insecticides to our test trees.

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[*] The costs of publication of this article were defrayed in part by the payment of charges from funds ma available in support of the research which is the subject of this article. In accordance with 18 U. S. C. § 1734, th article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

METHODS AND MATERIALS—We used 5 city blocks in a residential area of Oak-and Park, Broward Co., Florida for the test. Each block contained an average f 37 citrus trees of mixed species. The city blocks were divided into halves each ontaining roughly the same number of trees. One-half of each city block was reated with a spray regimen as described by McCoy et al. (1976); the other half vas untreated. The chemical control program consisted of 2 treatments. The first postbloom) was applied the week of 25 April 1977 and consisted of malathion 1.5 g AI/L) and Kocide® 101 (56% metallic $Cu(OH)_2$)(1.7 g AI/L). The second reatment was applied the week of 20 July and consisted of oil (FC-435)(10ml/L), nethidathion (0.3 g AI/L), benomyl (0.24 g AI/L) and chlorobenzilate (0.3 g I/L). All chemicals were applied with a hydraulic sprayer to the point of run-ff. Five trees were selected on each half-city block for a total of 25/treatment nd sampled bi-weekly from April-November 1977. No samples were taken the veek of 20 July but continued uninterrupted thereafter.

A total of 200 newly-matured leaves was taken from the 25 trees in each group nd a stereomicroscope was used to determine the presence or absence of the ollowing mites: Texas citrus mite, *Eutetranychus banksi* (McG.), six spotted pider mite, *E. sexmaculatus* (Riley), citrus red mite, *Panonychus citri* (McG.), nd citrus rust mite, *Phyllocoptruta oleivora* (Ashm.) Counts of the number of nites/leaf were not taken because economic thresholds are based on percent eaves infested (Brogdon and Lawrence, 1974) and sample variation was, as in revious studies (Muma, 1965), very large.

The number of mature female black scale, *Sassetia* spp. on 25 randomly hosen branch tips and the number of mature female citrus snow scale *Unaspis itri* (Comstock)/cm^2 of trunk were counted. We also sampled 625 randomly hosen leaves from the newest mature flush/25 trees for greasy spot (*Mycosphae-ella citri* Whiteside) a fungal disease of citrus (Whiteside, 1972), melanose, *Dia-orthe citri* (Faw) Wolf, and scales. The presence or absence of greasy spot and nelanose was noted and the number of live, female scales of the following species ounted: Yellow scale, *Aoindiella citrina* (Coq.), purple scale, *Lepidosaphes eckii* (Newm.), Florida red scale *Chrysomphalus aonidium* (L.) and lesser snow cale *Pinnaspis strachani* (Cooley).

RESULTS—We found no Texas citrus mites, six spotted spider mites, black cale, citrus snow scale, yellow scale, or melanose in our samples. An occasional itrus red mite was observed.

Table 1 shows the percentage of leaves infested with citrus rust mite on the reated and untreated trees. The trends seen on the treated trees especially the apid increase in the percentage of infested leaves that started in September, 1977 are typical for citrus rust mite populations in previous long-term studies Simanton, 1959 and 1976). The much sharper rise in the citrus rust mite infes-ation seen on the treated trees after the first spray may be due to mite resurgence fter the use of organophosphate insecticides (McCoy, 1977; Attiah and Wahba, 1971). The population trends of citrus rust mite seen on the treated trees from une onward are also typical of grove situations (Simanton, 1959 and 1976). Only n one occasion did the percentage of infested leaves in either treatment regimen

TABLE 1. Occurrence of citrus rust mites, greasy spot disease and scale insects on 50 citrus trees in Oakland Park, Florida, April to November, 1977.

	Percent of leaves with citrus rust mite		No. of leaves infected with greasy spot		No. of 3rd stage scale insects	
Date	Treated	Untreated	Treated	Untreated	Treated	Untreated
Pretreat						
4/13	32	18	141	71	105	100
Postbloom spray:						
5/9	31	22	129	64	90	89
5/23	39	22	80	46	75	70
6/7	59	29	13	22	39	49
6/20	54	13	24	13	10	11
7/5	53	22	21	8	10	48[°]
Summer spray:						
8/1	48	18	1	1	11	34[°]
8/15	31	28	2	2	4	39[°]
8/30	33	28	2	2	8	47[°]
9/13	36	27	4	9	3	36[°]
9/27	15	53	13	9	0	17[°]
10/10	13[+]	41	13	18	9	37[°]
10/24	22	67	1	3	4	18[°]
11/7	16	66	3	6	12	6
11/23	19	58	2	4	4	4

[+] Below economic threshold of 15% leaves infested set by Brogdon and Lawrence (1974).

[°] Significantly more scales on untreated trees ($P < 0.05$) as determined with a paired chi-square test (d.f. = 1).

drop below the economic threshold (15-20% Infested leaves) suggested by Brogdon and Lawrence (1974).

The total number of leaves infected with greasy spot declined rapidly on both the treated and untreated trees (Table 1). This decline is due to the dropping of the older infected leaves in the spring and early summer (Whiteside, 1970 and 1979). Few leaves (< 20/625 per sample) showed any sign of greasy spot from August to November. We feel the low occurrence of greasy spot on the sample trees is generally due to the removal of fallen leaves by the homeowner before they can decompose and release the infective stage of the disease.

Table 1 shows the total number of mature female purple, Florida red and lesser snow scales in each sample on treated and untreated trees. Although the spray regimens significantly ($P < 0.05$) lowered scale numbers from July to November, they never exceeded 0.2 scales/leaf in either plot and constituted no real problem. Table 2 is a more detailed analysis of the composition of the scales in the samples. Purple scale was the most abundant scale and lesser snow scale the least abundant on both treated and untreated trees. A correlation of individual scale numbers against the number of total scales showed that the changes in the number of purple scales accounted for the majority of the variation in the total number of scales observed on both treated ($r = 0.99$) and untreated ($r = 0.94$) trees. While the spray regimen significantly ($P < 0.05$) lowered the number of purple and lesser snow scales present, it had no effect on the numbers of

TABLE 2. Analysis of scale fauna on treated and untreated trees in Oakland Park, Florida from April to November, 1977.

	Total No. of Scales[a]	Purple Scale	Percent of Total	Florida Red Scale	Percent of Total	Lesser Snow Scale	Percent of Total
Treated	384°	215°	56	123	32	46°	12
Untreated	605	384	63	122	20	99	16

° Significantly different from untreated (chi-square, $P < 0.05$).
[a] Total number of leaves samples = 9375/treatment.

Florida red scale. Simanton (1976) found chemical sprays used over a 16 yr period had little effect on Florida red scale numbers in commercial citrus groves.

DISCUSSION—The spray regimen used herein had about the same impact on the citrus pests sampled on urban trees as one would expect on grove trees. It lowered the incidence of leaves infested with citrus rust mite, significantly lowered the numbers of purple scale, and had no impact on red scale numbers. There was no apparent interference with existing biological controls of purple, Florida red or black scales.

Whether an organism is considered a pest of citrus depends upon the tree's habitat setting. In commercial groves, the appearance of the tree is generally of a lesser consequence than the quality and quantity of the fruit produced. Organisms (e.g. aphids, mealybugs, etc.) that occasionally produce unsightly trees or leaves are usually ignored. Other organisms like citrus rust mites, which have little effect on the appearance of the tree but directly influence fruit quality, are considered to be key organisms in the pest management program (Simanton, 1976; McCoy et al., 1976). The situation is essentially reversed in the urban setting. Here the appearance of the tree is of paramount importance. Interest in fruit quality is limited to ascertaining if unsightly fruit can be eaten (Llewellyn and Goldweber, pers. comm.).

These differences manifest themselves in the composition of the pest complex to be controlled. In commercial citrus groves the key pests are citrus rust mite, greasy spot and citrus snow scale (McCoy et al., 1976; Simanton, 1976; Brooks and Whiteside, 1973). The current spray program is designed to control these pests while not interfering with the existing biological control of purple scale, Florida red scale and black scale (Selhime et al., 1969; Muma and Clancy, 1961; McCoy and Selhime, 1971; Muma, 1971).

None of the above pests are of much concern to the homeowner. Instead aphids, whitefly adults and sooty mold are most commonly brought to the Broward and Dade County Extension Agencies by homeowners. The presence of sooty mold on the leaves is the most common complaint from homeowners. While sooty mold may interfere with photosynthesis, the homeowners complaint is that it "makes their trees look bad". (Llewellyn and Goldweber, pers. comm.).

Homeowners want to know how to eliminate the sooty mold and must be in-formed that the mold develops on the excretions of certain insects and elimination of the mold first requires elimination of the insects producing it (Brogdon et al., 1976). Were there a way to eliminate just the sooty mold, most homeowners would do that and ignore its insect origins (Llewellyn and Goldweber, pers. comm.). While the objects of commercial citrus sprays (citrus rust mite and greasy spot disease) are present on urban citrus trees, the emphasis placed on tree aesthetics by the homeowner has relegated them to a non-pest status. Similarly, several usually unimportant organisms of commercial citrus (aphids, whitefly adults and sooty mold) are of importance on urban citrus trees because of their negative impact on the aesthetic quality of dooryard citrus trees.

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Biological Sciences

DISTRIBUTION AND STATUS OF THE ENDANGERED BIG CYPRESS FOX SQUIRREL (*SCIURUS NIGER AVICENNIA*) IN FLORIDA

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Abstract: *A survey based on personal interviews was conducted throughout the range of the Big Cypress fox squirrel* (Sciurus niger avicennia). *The subspecies is widespread in its original range, occurring in Hendry, Lee, Collier, Monroe, and northwestern Dade counties. The squirrels are rare and populations have very low density. The survey accounted for 340 squirrels, and presumably additional undetected individuals exist. The squirrels occupied cypress forest, pine savanna, tropical hardwood forest, oak savanna, mangrove forest, and suburban habitats; individuals may require more than one habitat. We recommend reclassification as a threatened subspecies and stronger protection from hunting.*[*]

The Big Cypress fox squirrel is a distinctive subspecies (Moore, 1954) that is adapted for terrestrial and arboreal life in the forests of southwestern Florida, where the annual cycle of flood and drought and frequent fires create special conditions. Formerly this squirrel occurred throughout the area south of the Caloosahatchee River, west of the true or tree island Everglades, and as far south as Cape Sable. More recently its range was thought to be reduced in the Big Cypress swamp and adjacent areas, and Layne (1974) and Brown (1973, 1976) stated that the squirrels were restricted to Collier County and northwestern Monroe County. Because of this reduced range, low population numbers, and increasing threats to occupied habitat, Big Cypress fox squirrels are considered in danger of extinction, have legal status as endangered, and are protected from hunting or other collecting (Game and Fresh Water Fish Commission, 1977). New information on distribution based on a questionnaire survey (Brady, 1977) conflicts with earlier studies by showing no reduction from the original range of the subspecies.

Methods—During January-March 1978, personal interviews were conducted with residents, hunters, and biologists throughout the range of S. *n. avicennia* as reported by Moore (1954). Because of the distinctive appearance of fox squirrels, we were able to differentiate to our satisfaction sightings of fox squirrels from those of gray squirrels (*Sciurus carolinensis*). Sightings reported here are ones we considered valid and very recent. Efforts were made to confirm sightings by personal observations in the field.

Range—The distribution of S. *n. avicennia* as of 1978 is shown in Fig. 1. We were able to confirm occurrence at 6 of the 48 localities by firsthand sightings. Populations occur in Hendry, Lee, Collier, Monroe, and northwestern Dade

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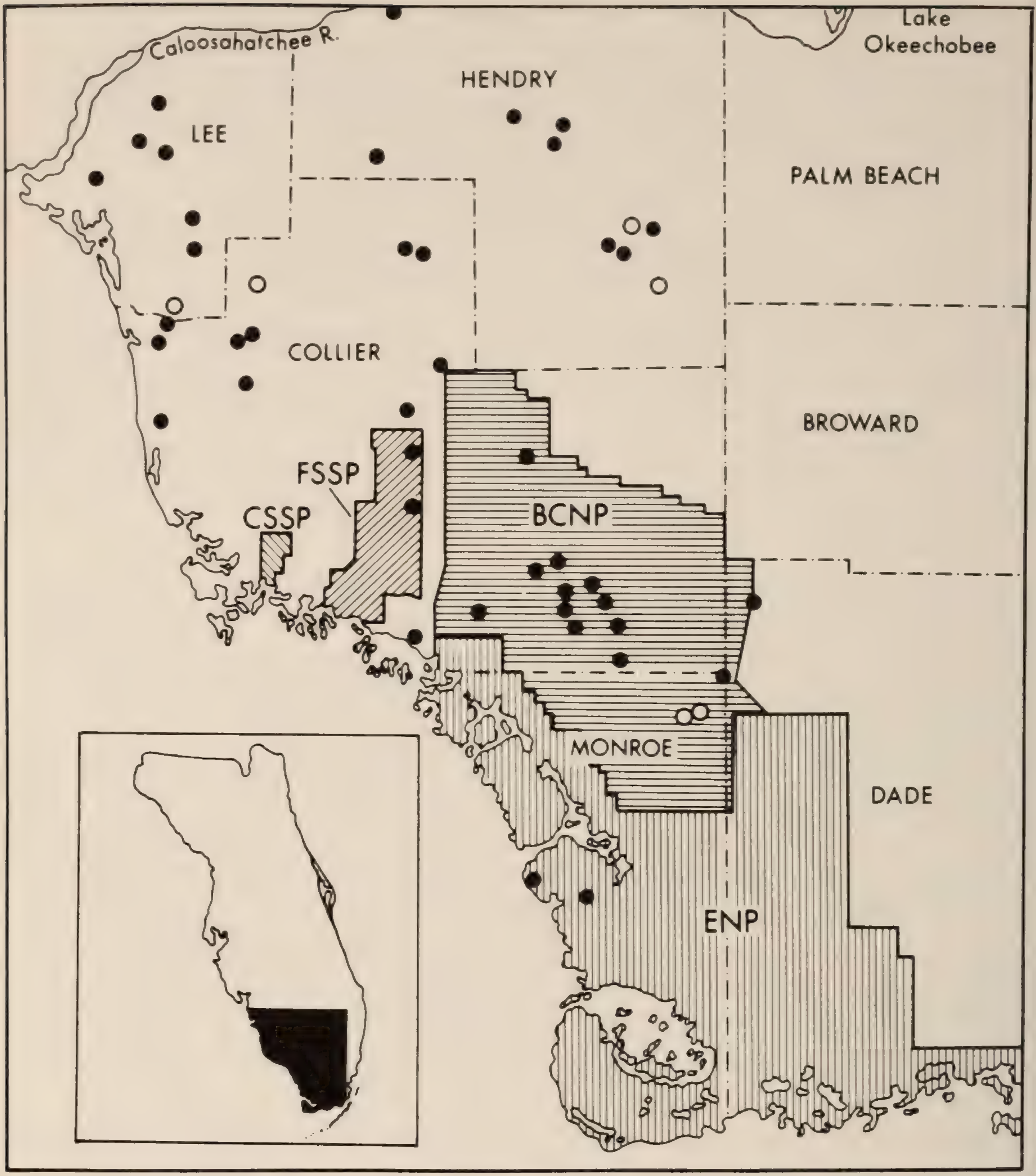

FIG. 1. Distribution of S. *n. avicennia*. Open circles are our sightings and closed circles are reported sightings or specimens. Large tracts of public land indicated by initials are Collier-Seminole State Park, Fakahatchee Strand State Preserve, Big Cypress National Preserve, and Everglades National Park.

counties. Most sightings (26) were in Collier County and only 1 was in Dade County.

STATUS—The number of S. *n. avicennia* seen or estimated at the localities ranged from 1-30, averaging 7.2. The total number represented on Fig. 1 is approximately 340 individuals. Because most observations are made near roads, we assume additional fox squirrels were present but not detected in this survey.

These observations provided estimates of fox squirrel density at two sites. At Corkscrew Swamp Sanctuary, 4 occurred on 4,338 ha. On a ranch in Hendry County, 30 occurred on 1,554 ha. Densities at these places were 1 squirrel per

1,084 and 52 ha, respectively. These calculations are based on total sizes of the surveyed tracts, including both occupied and unoccupied habitats.

HABITATS—S. *n. avicennia* uses a wide variety of habitats, occupying most types of forests in its range. Only the dense interiors of cypress domes and strands are rarely used by fox squirrels; usually these are inhabited by gray squirrels. Several of the biologists interviewed thought that the seasonal availability of food determined habitat use by S. *n. avicennia.* However, no detailed information on diet is available and cover for shelter appears to be important as well. Consequently, many questions about habitat use are unanswered.

The sightings shown in Fig. 1 documented S. *n. avicennia* in cypress forest, pine savanna, tropical hardwood forest, oak savanna, mangrove forest, and suburban habitats. Most sightings were in cypress (*Taxodium distichum*), slash pine (*Pinus elliotii*) savanna, or at the interface of these 2 habitats. Our limited observations at Corkscrew Swamp Sanctuary support an apparent dependence on both cypress and pine. During the winter dry season, we observed that S. *n. avicennia* forages on the ground and in the savanna trees through the morning and at midday retreats to the cypress edge. Here the cypress occurs in dense stands of young, small trees, resulting from occasional fires at times of drought (Duever et al., 1976). During the summer rainy season, S. *n. avicennia* are reported by Sanctuary staff to "disappear," which may represent full-time residence in the cypress edge (where human visibility is limited) without use of the pine habitat. Squirrel nests did not occur in the pine savanna, where cover from predators and storms may be inadequate.

On the topographically high area north of the Big Cypress Swamp in Hendry and northern Collier counties, large areas of former upland prairie, pine savanna, and marshland have been drained and converted to pasture. Scattered live oak (*Quercus virginiana*) savannas on this ranchland are occupied by S. *n. avicennia.* Grazing by cattle hinders development of a forest understory and may enhance the habitat for fox squirrels. Fox squirrel density in this habitat was much higher than in undisturbed habitats in the Big Cypress.

Mangrove forest appears to account for a small portion of the occupied range (4 localities in Fig. 1) and supports a small number of squirrels. As with other habitats, the extent to which S. *n. avicennia* uses mangrove forest alone or in conjunction with other habitats is unclear.

S. *n. avicennia* have persisted in areas developed for human residence where the trees comprising native squirrel habitat have been preserved. The addition of ornamental plantings, birdfeeders, and handouts have supplemented and stabilized food resources. About half of the localities in Lee County are in such suburban habitats. Developed sites occupied by fox squirrels included golf courses, city parks, and residential areas on original habitats including pine savanna, the upland fringe of cypress, and tropical hardwood forest. The well-known population at Everglades City (Moore, 1954) lived in the city park until its trees were destroyed by a hurricane in 1960. In cases where development has been accompanied by thorough removal of trees, loss of squirrel populations has been nearly complete. This was the case for the intergrades (Moore, 1954) of

Sciurus niger shermani and S. *n. avicennia* that inhabited the pine savanna and tropical hardwoods in eastern and southern Dade County until the 1930s or 1940s.

Discussion—The distribution of the Big Cypress fox squirrel is somewhat larger than originally documented by Moore (1956). This result coincides with that of Brady (1977). The large range now occupied probably represents improved documentation rather than a historical expansion of range.

The small number of individuals found here shows that S. *n. avicennia* is rare. This conclusion has been reached by all authors beginning with Howell (1919), and the low densities recorded here may be an inherent feature of the subspecies in the Big Cypress Swamp. Rarity is exaggerated by our density estimates because much unoccupied habitat is included in the computations. More precise density calculations must await a better understanding of habitat requirements. By contrast, S. *n. shermani* in prime longleaf pine-turkey oak habitat in northern Florida occurred at a density of one per 2.6 ha (Moore, 1957). Densities of S. *n. rufiventer* in the midwestern United States are strikingly higher. For example, springtime census with traps in Michigan revealed averages of 3.2 fox squirrels per ha in oak-hickory woodlots, 2.7/ha in beech-maple forest and in scrub oak savanna, and 0.1/ha in swamp forest (Allen, 1943).

No previous estimate of S. *n. avicennia* numbers exists, so population trend is not clear. Brady (1977) reported stable populations in Monroe, Collier, and Hendry counties and no consensus in Lee County. However, in the Hendry County ranchland where opportunity for observation is frequent and repetitious, ranchers told us that there are more fox squirrels in the oak savannas "now that we can't shoot them."

The closed hunting season is less strictly observed in other areas, where we received numerous reports of illegal hunting. The impact of hunting is not known. Hunter survey records of the Florida Game and Fresh Water Fish Commission for 5 sections of the Big Cypress Swamp estimate the harvest of fox squirrels at 258 individuals over a 3-yr period from 1952 to 1955. Because the rate and season of reproduction are unknown, the ability of S. *n. avicennia* to respond to hunting pressure cannot be evaluated. In Ohio, Baumgartner (1943) and Nixon et al. (1974) reported overharvest of fox squirrels that inhabit small woodlots, where ease of access enabled demand by hunters to exceed the supply of squirrels. Because suitable habitat there was discontinuous, immigration was infrequent and population recovery was slow. Similar conditions should prevail for the low-density populations of Big Cypress fox squirrels, particularly where they occupy isolated types of habitats such as live oak savannas and tropical hardwood hammocks.

Ground fires are considered of major importance to fox squirrels (Robertson, 1953; Brown, 1976) in retarding succession of understory plants, but no studies of this relationship have been made. Light grazing likewise maintains the sparse ground cover favored by fox squirrels and may account for the relatively high density found on Hendry County ranchland. In Ohio woodlots, Baumgartner (1938) concluded that fox squirrels occurred at higher densities (1.61/ha) on grazed plots than ungrazed sites (1.11/ha). Similarly, in Michigan Allen (1943) found 5.0 fox squirrels per ha in grazed woodlots but only 3.0/ha in ungrazed woodlots.

Habitat destruction is considered by all to be the major limiting factor to Big Cypress fox squirrels. Recent acquisition of the Fakahatchee Strand State Preserve and the Big Cypress National Preserve (see Fig. 1) are important advances in the conservation of these squirrels. Because geographic range is as large as it was prior to development, and because no evidence of a population decline exists, S. *n. avicennia* clearly is not in imminent danger of extinction. Continuing loss of habitat in the range of the subspecies poses a threat, so protection as a threatened subspecies is appropriate. The inherently low numbers and densities and the frequency of illegal hunting demonstrates a need for stronger law enforcement and hunter education. For these reasons we recommend that the State of Florida reclassify S. *n. avicennia* from "endangered" to "threatened" and strengthen protection from hunting.

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Biological Sciences

A REPRODUCING POPULATION OF *SERRASALMUS HUMERALIS* VALENCIENNES IN SOUTHERN FLORIDA[1]

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Abstract: *An isolated reproducing population of the pirambeba,* Serrasalmus humeralis, *was recently discovered at a Dade County, Florida tourist attraction. Twenty to 25 unidentified* Serrasalmus *sp. had been stocked into the 'piranha pool' in 1963 or 1964. The only fish kill noted during the 13 to 14 yr history of this population occurred during a severe drought in 1971 when the pool dried into a small mud-puddle. A few* S. humeralis *survived this drought and continued reproducing. When renovated, the piranha pool yielded 53 pirambebas in 3 distinct size classes ranging from 21-305 mm and 0.1-830 g. A lower lethal temperature of 11°C was identified when these fish were subjected to decreasing water temperatures at a rate of 1°C/day. This lethal temperature and an analysis of mean monthly temperatures suggest there is more suitable serrasalmin habitat in Florida than previously recognized.* Serrasalmus humeralis *were found to be relatively tolerant to rotenone with one individual surviving a 72 hr exposure to 2 ppm 5% emulsified rotenone. This population substantiates previous conclusions that members of the genus* Serrasalmus *can become established in Florida.*°

A reproducing population of the pirambeba, *Serrasalmus humeralis* Valenciennes (Fig. 1), was recently discovered during a routine inspection of a Dade County, Florida tourist attraction. The population was confined to a small sinkhole surrounded by steep banks and dense terrestrial vegetation. This finding substantiates Moe's (1964) conclusion that the establishment of *Serrasalmus* spp. is possible in Florida.

Members of the genus *Serrasalmus* are divided into 2 major groups, the piranhas and pirambebas. Both groups have the well-developed dentition that characterizes this genus. The piranhas have a convex, more muscularized forehead than the pirambebas which have a relatively concave forehead. True piranhas are considered more dangerous to man, although the pirambebas should not, in this regard, be totally ignored. Both are considered generalistic stenophagic carnivores capable of causing "havoc amongst other fishes . . ." (Myers, 1965, p. 54). The pirambebas are effective piscivores, removing neat pieces of flesh from the posterior sections of their prey in the typical piranha fashion.

Regardless of one's opinions on the threat members of this genus pose (Schultz, 1960; Myers, 1972b), it is agreed that these fish would not be a welcome addition to the Florida fish fauna. We discuss the history, general habitat and

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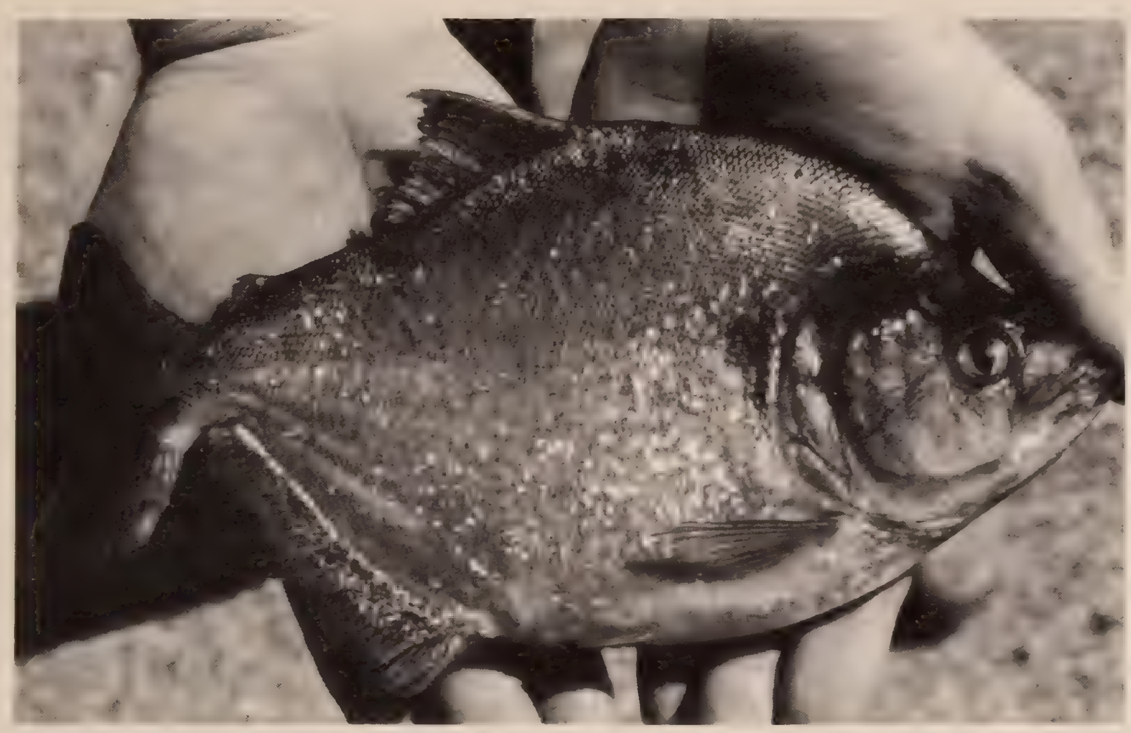

FIG. 1. Photograph of adult *Serrasalmus humeralis*.

renovation data for this population in addition to reporting lower lethal temperatures and rotenone toxicity data for this species.

HISTORY—The population of *S. humeralis* was first discovered in March 1977. The fish were located in a small, confined sinkhole at Monkey Jungle, 14805 S.W. 216th Street, Miami, Florida. According to Mr. Frank V. Dumond, Director at Monkey Jungle, 20-25 'piranha' of an unidentified species were stocked into the pool in 1963 or 1964. These fish measured 76 mm or less at the time of stocking. No subsequent stockings of the pool were made.

These fish were fed cut fish daily by Monkey Jungle personnel. During the winter of 1976-1977, Florida experienced one of its coldest winters on record. The only noticeable effect on these fish was a temporary 4-6 wk cessation of feeding. The only dead *S. humeralis* observed during the 13-14 yr history of the population died during the severe drought of 1971 when the pool dried into a small "mud-puddle." It was believed that all 'piranhas' had died at this time because none was observed as the water table rose and refilled the pool. Feeding of the 'piranha' was discontinued until 1-2 yr later when survivors and their offspring were observed.

Seven specimens, representing 3 distinct size classes, were collected from the piranha pool in March 1977 with a small seine and dip nets. These specimens ranged in size from 56-235 mm total length and weighed between 3.2 and 397 g. The largest pirambeba was a mature female, the preserved ovaries of which weighed 4.1 g. The ovaries contained eggs in 3 developmental stages: primary oocytes, developing, and mature ova.

HABITAT—A small, well-fed stream flows through an artificial rain-forest and empties over a 3-4 m waterfall into the piranha pool. The pool measures about 10 × 15 m, the depth of which varies with the season (maximum depth observed about 2.2 m). In the center, the bottom was covered with 30 to 45 cm of detritus. There is no surface outlet from the pool. Numerous poeciliids inhabited the shallow areas of the pool. In April 1977 water chemistry samples were taken from the pool (Table 1).

TABLE 1. Summary of the water chemistry data taken from piranha pool on 4 April 1977. All results expressed as mg/l unless otherwise noted.

Test	Piranha Pool
Temperature (°C)	25.0
Dissolved Oxygen	7.4
pH	8.0
Specific Conductance (Micromhos/cm)	650
Total Residue (180°C)	367
Sulfate	55.0
Turbidity (JTU)	
Unfiltered	6
Filtered	6
Calcium	106.4
Magnesium	2.6
Sodium	7.9
Potassium	6.0
Chloride	70.0
Iron (Total)	0.02
Nitrate Nitrogen	3.30
Ammonia Nitrogen	0.10
Organic Nitrogen	0.34
Ortho Phosphate (as PO_4)	0.03
Total Phosphate (as PO_4)	0.09
Chlorophyll a (mg/m^3)	0.0
Phaeophytin (mg/m^3)	3.2

IDENTIFICATION—The diagnostic characters used to identify these fish as S. *humeralis* included: 1. Presence of strong ectoptergoid teeth, 2. Third infraorbital does not entirely cover the cheek, 3. Body depth is less than two times the standard length in specimens greater than 100 mm, 4. Dorsal fin with 15-17 principal rays and 14-16 branched rays, 5. Anal fin with 29-34 principal rays and 28-33 branched rays, 6. Caudal fin with dark margin in specimens greater than 100 mm SL (J. S. Ramsey, Auburn Univ. and W. L. Fink, Harvard Univ., pers. comm.). Representative specimens of S. *humeralis* from this population were deposited in the fish collections at Auburn, Harvard and Florida Atlantic Universities.

The second diagnostic character separates S. *humeralis* from the white piranha (S. *rhombeus*). If the third infraorbital entirely covered the cheek, these fish would key out as white piranha. Because the phylogenetic significances of the infraorbital size is not known (W. L. Fink, pers. comm.) and considering the current confusion surrounding the classification of piranhas (Myers, 1965 and 1972a), it is possible that S. *humeralis* may eventually be considered as a synonym of the white piranha. There is no accepted common name for S. *humeralis*.

RENOVATION DATA—All of the S. *humeralis* inhabiting the piranha pool were killed or removed alive in September 1977 with rotenone. Five percent emulsified rotenone was applied at a rate of 6.25 ppm during a 20-30 min period. Fingerlings (<80 mm total length) began appearing approximately 45 min after rotenone was first added; larger individuals appeared about 15 min later. Stressed but active fish were picked up for nearly 2 hrs, after which only a few small dead fish were observed. The pool was checked on the following day and all dead fish removed. Limited shoreline accessibility, undercut ledges and the moderate turbidity at the time of renovation prevented collection of all dead fish.

A total of 53 S. *humeralis* was collected from the pool. These fish ranged in size from 21-305 mm total length and weighed between 0.1 and 830 g. A length-frequency histogram for these fish support our preliminary findings that the population was composed of 3 distinct size classes and confirmed its reproductive status (Fig. 2). The length-weight regression analysis for 47 S. *humeralis* taken from the renovated piranha pool was $\log_{10}WT = -5.24 + 3.25 \log_{10} TL$ ($r = .9958$).

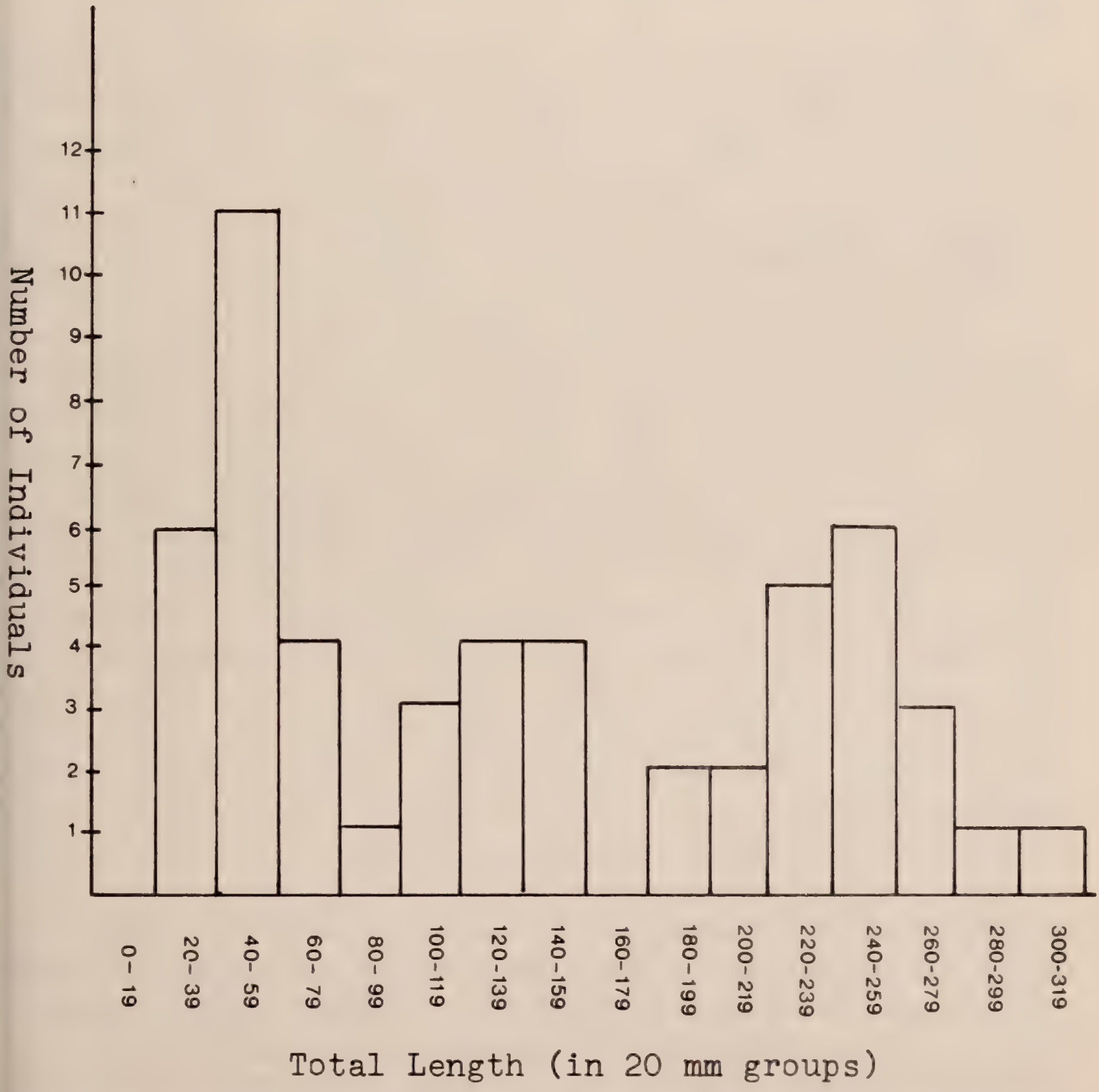

FIG. 2. Length-frequency distributions of the *Serrasalmus humeralis* population collected during the renovation process on 7 September 1977.

An effort was made to revive some rotenone stressed S. *humeralis* so they could be used in temperature and rotenone bioassay studies. Twenty-three fish were placed in fresh water where they regained equilibrium within 30 min. Only 1 specimen died while enroute to the laboratory.

Stomachs of 30 S. *humeralis* ranging in size from 21-251 mm total length were removed and the contents identified. One to 7 poeciliids were found in each of 16 individuals measuring 31-145 mm total length. No poeciliids were found in specimens measuring >145 mm. Pieces of cut fish were found in 7 fish (40-251 mm total length). Sixteen others (35-251 mm total length) contained fish scales, some of which were stacked together. A 30-mm individual had consumed the caudal fin of a similar sized S. *humeralis* and the 21-mm specimen contained a dipteran larva and a small crustacean. No S. *humeralis* stomach was empty although 7 contained only fish scales. Stomach contents reported here may not be an accurate description of food habits because these fish were collected with rotenone.

TEMPERATURE STUDIES—Eight S. *humeralis* were placed in a temperature control system which was adjusted to 25°C. The temperature control system consists of a cold water reservoir, eight 190-l aquaria with individual temperature controls (±0.1°C) and a collection and return box. Air-lifts provided an even mixing and oxygenation of the water within the aquaria. The S. *humeralis* were acclimated in the system at 25°C for 8 days. Starting on the ninth day, the water temperature was decreased in 6 of the aquaria at a constant rate of 1°C/da. Two aquaria were maintained as controls at 25°C throughout the study. Daily monitoring included: (1) replacing any eaten food fish, (2) observing the fish for behavioral changes associated with each decrease in temperature, and (3) maintenance of adequate water quality which involved exchanging approximately 10% of the system's water volume and siphoning feces from each chamber.

Four of the S. *humeralis* died at 12°C and 2 at 11°C. No parasites were observed on these fish which were examined shortly after dying. One S. *humeralis* did not feed during the study and 3 others ceased feeding before the temperature was dropped to 20°C. None of the S. *humeralis* fed below temperatures of 15°C. Loss of equilibrium started with the S. *humeralis* orienting vertically, the head pointed up. All fish exhibited losses of equilibrium between the temperatures of 12-14°C, except for one which lost equilibrium at 16°C. An inactive horizontal position was exhibited by all fish prior to dying. The S. *humeralis* used in this study measured 133-288 mm total length and weighed 43-574 g. The control fish remained healthy and continued feeding throughout this study.

Mean monthly air temperatures can be used to predict water temperatures in Florida (Anderson, 1975). Using the mean monthly air temperatures for January, normally Florida's coldest month of the year (Bradley, 1974), and the lower lethal temperatures identified here, areas where S. *humeralis* could become established in Florida are given in Fig. 3. As this map illustrates, suitable water temperatures for the acclimatization of S. *humeralis* likely exist over much of Florida. In fact, nowhere in Florida can be entirely excluded.

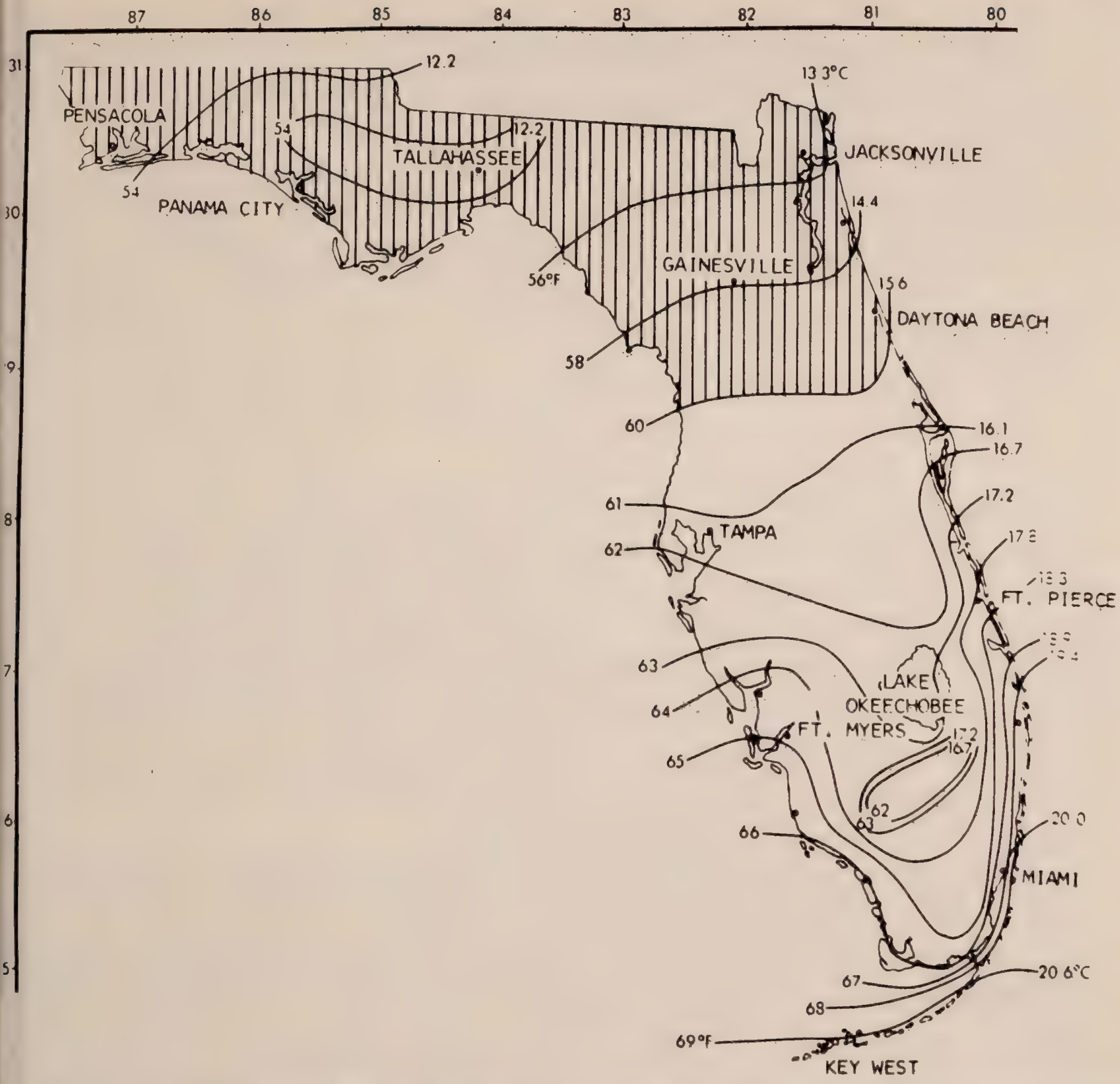

Fig. 3. No area in Florida can be entirely excluded with regard to the possible acclimatiza-ion of *Serrasalmus humeralis* although areas north of the 15.6°C isotherm provide increasingly less uitable winter stream temperatures (isotherms from Thomas, 1974; Wood and Fernald, 1974).

Rotenone Toxicity—Rotenone stressed fish from the above described popu-ation were revived in fresh water and held in a 2300-1 aquarium for 3 wk prior o initiating this preliminary rotenone toxicity study. Two trials were made sing 5 aquaria filled with 60-1 of dechlorinated city water. Initial water temperature, pH and dissolved oxygen readings in this study ranged from 25.6-26.8°C, 7.95-9.10 and 7.9-8.7 ppm, respectively. The Boca Raton Municipal Water Treatment Plant reported water hardness was about 80 ppm $CaCo_3$ on the days aquaria were filled. One fish was added to each aquarium and observed or 72 hr. The aquaria were not aerated during the observation period. The fish sed in this study measured 199-305 mm total length and weighed 167-830 g. No ontrol fish died during these tests.

Serrasalmus humeralis died in Noxfish® concentrations of 5 and 7 ppm within 9 hr while the 2 fish exposed to 3 ppm died within 53 hr. Two of the fish xposed to 2 ppm Noxfish® died within 25 hr although a third fish exposed to 2 ppm Noxfish® survived. The single fish exposed to 1 ppm Noxfish® survived the 72 hr observation period. Cause of death for 2 fish exposed to 2 and 3 ppm Noxfish® was complicated by low dissolved oxygens of 0.4 and 0.6 ppm although S. *humeralis* surviving the study were exposed to similar concentrations and exhibited no apparent signs of stress.

This study does not identify specific lethal doses of rotenone for S. *humeralis* but does demonstrate that they are relatively tolerant to it. These data indicate that it is unlikely S. *humeralis* could be selectively managed with rotenone in our aquatic ecosystems. We also suggest that S. *humeralis* can survive in waters with a low dissolved oxygen content.

DISCUSSION—Serrasalmins, like other members of the family Characidae, are strictly freshwater fishes. *Serrasalmus* spp. do not occur in the swift water o rapids (Myers, 1949), but in nearly all other types of aquatic environments within their geographic range (Moe, 1964; St. Amant, 1967). They seem to prefer the clean, quiet, deep pools of small slow-moving rivers (Myers, 1949) although they survive well in small, shallow and muddy potholes during the dry season (V. E. Ogilvie, Florida Game and Fresh Water Fish Commission, pers. comm.) In a Brazilian survey, 1,063 of 4,073 small pools treated with rotenone produced members of the genus *Serrasalmus* (Anonymous, 1962). Reservoirs also provide suitable habitat for serrasalmins as is demonstrated by S. *rhombeus* in Brazil's Lima Campos Reservoir. Here, S. *rhombeus* comprised 40.8% of the catch among 8 species during a 10-yr period (Braga, 1954).

Observations of spawning behavior in aquaria confirm that *Serrasalmus* spp guard their young (Braker, 1960 and 1963; Anonymous, 1963; Ledecky, 1966) This protective behavior is an unusual characteristic for a characin. Aquarium spawnings of *Serrasalmus* spp. report that as many as 5,000 eggs are released per spawn at intervals of 1-4 wk and that the young grew to 19 mm in 6 wk and 44 mm in 14 wk (Anonymous, 1963; Braker, 1960 and 1963; Ledecky, 1966). Several authors have suggested the serrasalmins spawn in a nearly cichlid fashion particularly with regard to spawning periodicity and the parental care given to young (Schultz, 1960; Axelrod, 1970). They deposit adhesive eggs in tree roots dangling in the water (Lowe-McConnell, 1975) or in the roots of floating plants such as the water hyacinth (Ledecky, 1966). These general spawning conditions occur throughout much of Florida, enhancing the possibility of their establishment here.

Moe (1964) and St. Amant (1967) surveyed available information and concluded that at least some *Serrasalmus* spp. were biologically capable of establishing reproducing populations in southern parts of the United States. Low water temperature was considered the single most important factor determining whether or not these fishes can be established outside their natural range. St Amant (1967) reports winter sublethal acclimatization temperatures of 7 to 8°C for *Serrasalmus* spp. The lower lethal temperatures identified in this study demonstrate conclusively that winter water temperatures will not prohibit establishment of S. *humeralis* in Florida. Similarly, it is likely that the most widespread and notorious of the true piranhas, S. *nattereri*, as well as other *Serrasalmus* spp are capable of becoming established here.

CONCLUSIONS—The existence of this reproducing population of S. *humeralis* substantiates the conclusions of earlier reports that some aquatic ecosystems in the United States offer suitable habitats for the establishment of *Serrasalmus* spp. Winter water temperatures will not prohibit *Serrasalmus* spp. from becoming established in Florida where there exists an abundance of prey and where the aquatic vegetation (e.g., water hyacinths) offers suitable spawning sites. More aquatic environments in Florida provide apparently suitable habitats for the serrasalmins than was previously recognized. To what extent *Serrasalmus* spp. would alter existing aquatic ecosystems cannot be predicted but that they would not be a beneficial addition is a certainty. In fact, such introductions would likely cause costly and catastrophic results.

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STUDIES OF THE FLORIDA CONVOLVULACEAE-I. KEY TO GENERA

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ABSTRACT: *A key to the genera of the plant family Convolvulaceae is presented in preparation for a modern analysis of the species in Florida.**

THE morning glory family (Convolvulaceae) in Florida has changed little in species composition since the preparation of John K. Small's (1933) "Manual of the Southeastern Flora," but the taxonomy has been in flux. Generic concepts have changed and interpretation of taxa has been altered by continued research. Some of the taxa have been discussed recently (Tharp and Johnston, 1961; Myint, 1966; Myint and Ward, 1968; Ward, 1968; Lewis, 1971; Austin, 1973, 1975, 1976, 1977a, 1977b, 1978a, 1978b; Austin, Powell and Nicolson, 1978; Powell, Nicolson and Austin, 1978), but no analysis has been given for the plants within Florida. To bring the systematics in line with modern thought, keys to genera will be presented first. Generic and specific examinations with keys and illustrations will follow.

1. Plants parasitic; stems orange to yellow, without chlorophyll; leaves reduced to scales or absent; flowers 1.5 - 5 mm long; styles mostly 2 and distinct, rarely 1; fruits capsular, opening either by circumscission or irregularly; cotyledons absent. .... 1. *Cuscuta*

1. Plants autotrophic; stems green or brown, chlorophyllous; leaves present and fully formed although variable; flowers 4-6 mm long (*Dichondra, Evolvulus, Porana*) or more commonly 1 cm long or more; styles 1 or 2 and free (*Bonamia, Dichondra, Stylisma*); fruits mostly capsular and opening by valves or irregularly, subbaccate in *Argyreia*; cotyledons present.

2. Herbs, prostrate, to 1 m long; flowers mostly solitary in leaf axils; calyx connate basally, deeply 5-lobed; fruits deeply 2-lobed or almost 2 and separate, utriculate, tardily irregularly dehiscent .... 2. *Dichondra*

2. Vines, herbs or shrubs, twining or suberect, rarely procumbent or prostrate, mostly over 1 m long if twining, smaller if erect or ascending; flowers solitary or more commonly cymose to paniculate; calyx lobes free; fruits entire, capsular and opening by valves or indehiscent.

3. Fruits indehiscent, fleshy to dry and lignescent; large woody vines; flowers white, lavender to scarlet; mostly cultivated plants.

4. Corollas to 5-6 mm long, white .... 3. *Porana*

4. Corollas longer than 1 cm, white with a purple throat within, lavender or scarlet.

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*The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U.S.C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

5. Sepals enveloping the fruits; flowers scarlet, often with yellow stripes .... 4. *Stictocardia*
5. Sepals reflexed in fruits; flowers white or purple.
6. Corolla white, often dark within at base with brown to purple; filament bases with orange glandular trichomes; fruits with enlarged sepals, dry; seeds 1 or rarely 2, glabrous to puberulent .... 5. *Turbina*
6. Corolla purple, darker inside tube; filaments white at base although with glandular indumentum; fruits without enlarging sepals, subbaccate; seeds 1 to 4 glabrous .... 6. *Argyreia*

3. Fruits dehiscent, dry and capsular; herbs, shrubs, twining vines, or rarely woody lianas; flowers white, yellow, orange, pink, red or lavender; mostly wild plants, some cultivated.
7. Flowers mostly less than 2 cm across, broadly campanulate to subrotate, white or blue; small vines or diffuse, ascending to suberect suffrutescent herbs, mostly herbaceous.
8. Herbs or small suffrutescent shrubs, not scandent; styles 2; stigmas 4, elongate and clavate or linear .... 7. *Evolvulus*
8. Vines, scandent or procumbent; styles 1 or 2; stigmas either globose or ellipsoid to oblong.
9. Style 1; stigmas ellipsoid to oblong .... 8. *Jacquemontia*
9. Style 2; stigmas globose .... 9. *Stylisma*
7. Flowers mostly more than 2 cm across, funnelform, salverform or broadly campanulate (*Aniseia*, *Merremia*), yellow, white, red, orange, blue or pink; large to small vines, herbaceous to woody.
10. Bracts enlarged with two surrounding and obscuring the calyx; corollas funnelform, white or tinged with pink .... 10. *Calystegia*
10. Bracts squamiform, shorter than the pedicel and not surrounding the calyx; corrollas campanulate to funnelform to salverform, white, blue, lavender, orange to red.
11. Corollas blue; styles 2 and free; prostrate to ascending herbs in the pine scrub of the central Florida ridge .... 11. *Bonamia*
11. Corollas white, yellow, lavender, orange to red; styles 1; mostly ascending or twining vines, rarely prostrate, found in a variety of habitats but uncommon in pine scrub.
12. Corollas white, lavender, orange or red, funnelform or salverform; pollen pantoporate, spinulose .... 12. *Ipomoea*
12. Corollas white, white with a red to purple center or yellow; pollen colpate, smooth.
13. Outer 2 sepals enlarged and surrounding the lower third to half of the broadly campanulate, white corolla.
.... 13. *Aniseia*
13. Outer sepals more or less the same size as the inner, at least not markedly larger and not surrounding the lower third to half of the white to yellow corolla .... 14. *Merremia*

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Biological Sciences

STUDIES OF THE FLORIDA CONVOLVULACEAE -II. *MERREMIA*

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Abstract: *Field and herbarium studies confirm 5 native, naturalized or adventive* Merremia *in Florida. Two of the species have not been recorded previously. Keys and illustrations are given with other data.*[*]

Merremia is a tropical and subtropical genus of 60 or more species which has been divided into artificial sections by O'Donell (1941). Small (1933) and others have confused this genus with *Operculina*; fruit dehiscence is operculate in *Operculina* while it is valvate or irregular in *Merremia*. The genus is said to have been named for Blasius Merrem (1761-1824), a German professor.

Florida distributions reported here are based on specimens deposited at the Fairchild Tropical Garden, Field Museum of Natural History, Florida Atlantic University, Florida State University, Missouri Botanical Garden, New York Botanical Garden, University of Florida and University of South Florida.

Merremia Dennstedt, Schluess. Hort. Malab. 34. 1818. Type: *M. hederacea* (Burm. f.) H. Hallier (= *M. convolvulacea* Dennstedt).

Skinnera Choisy, Mem. Soc. Phys. Geneve 6:487. 1834, non Forst. (1776). Type: *S. caespitosa* Choisy (= *Merremia hirta* (L.) Merrill).

Spiranthera Bojer, Hort. Maurit. 226. 1837, nomen nudum, non St. Hil. (1823).

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[*]The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U.S.C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

Vines or lianas; stems herbaceous at tips. Leaves entire, lobed or palmately compound with 3 - 7 leaflets, glabrous or pubescent. Inflorescences solitary or of few-flowered dichasia or sub-umbelliform. Flowers with linear or lanceolate bracts; sepals subequal, oblong to elliptic; corollas mostly campanulate, usually white or yellow, some with purple throats; the filaments equal or subequal, mostly glabrous at the base, the anthers spirally twisted with complete dehiscence, the pollen 3-colpate, less commonly pantocolpate or pantoporate; ovary usually glabrous, 2 - 3-carpelled, the style filiform, the stigma globose or biglobose, included. Fruits capsular, 2 - 4-celled, longitudinally dehiscent by 4 - 6 valves or frequently irregularly dehiscent, the pericarp thin and fragile; seeds 1 - 4(-6), glabrous or pubescent.

1. Leaves narrowly triangular to ovate, entire. Inflorescences subumbellate to rarely solitary. Flowers yellow. Pollen pantocolpate. 5. *M. umbellata*

1. Leaves almost circular to broadly ovate in outline, deeply palmately lobed to palmately compound. Inflorescences typically solitary, occasionally in 2's or 3's. Flowers white (with or without reddish to purplish centers), or yellow. Pollen 3-colpate.
    2. Leaves deeply palmately lobed but not compound, the lobes connected by some tissue at the base.
        3. Lobes of leaves entire. Flowers yellow, broadly funnelform to campanulate-funnelform. Woody perennial vines. 4. *M. tuberosa*
        3. Lobes of leaves sinuate to crenate. Flowers white with purplish to reddish centers, broadly campanulate. Suffrutescent vines. 2. *M. dissecta*

    2. Leaves palmately compound, the segments distinct.
        4. Sepals and stems densely pubescent with erect trichomes on the sepals. 1. *M. aegyptia*
        4. Sepals and stems glabrous or with glandular trichomes on the sepals. 1. *M. quinquefolia*

1. *Merremia aegyptia* (L.) Urban, Symb. Antill. 4: 505. 1910.

Ipomoea aegyptia L., Sp. Pl. 162. 1753. Type: West Indies. LINN 218.35 (holotype LINN, n.v.,; microfiche seen).

Convolvulus pentaphyllus L., Sp. Pl. ed. 2. 223. 1762. Type: based on the same type as *Ipomoea aegyptia*.

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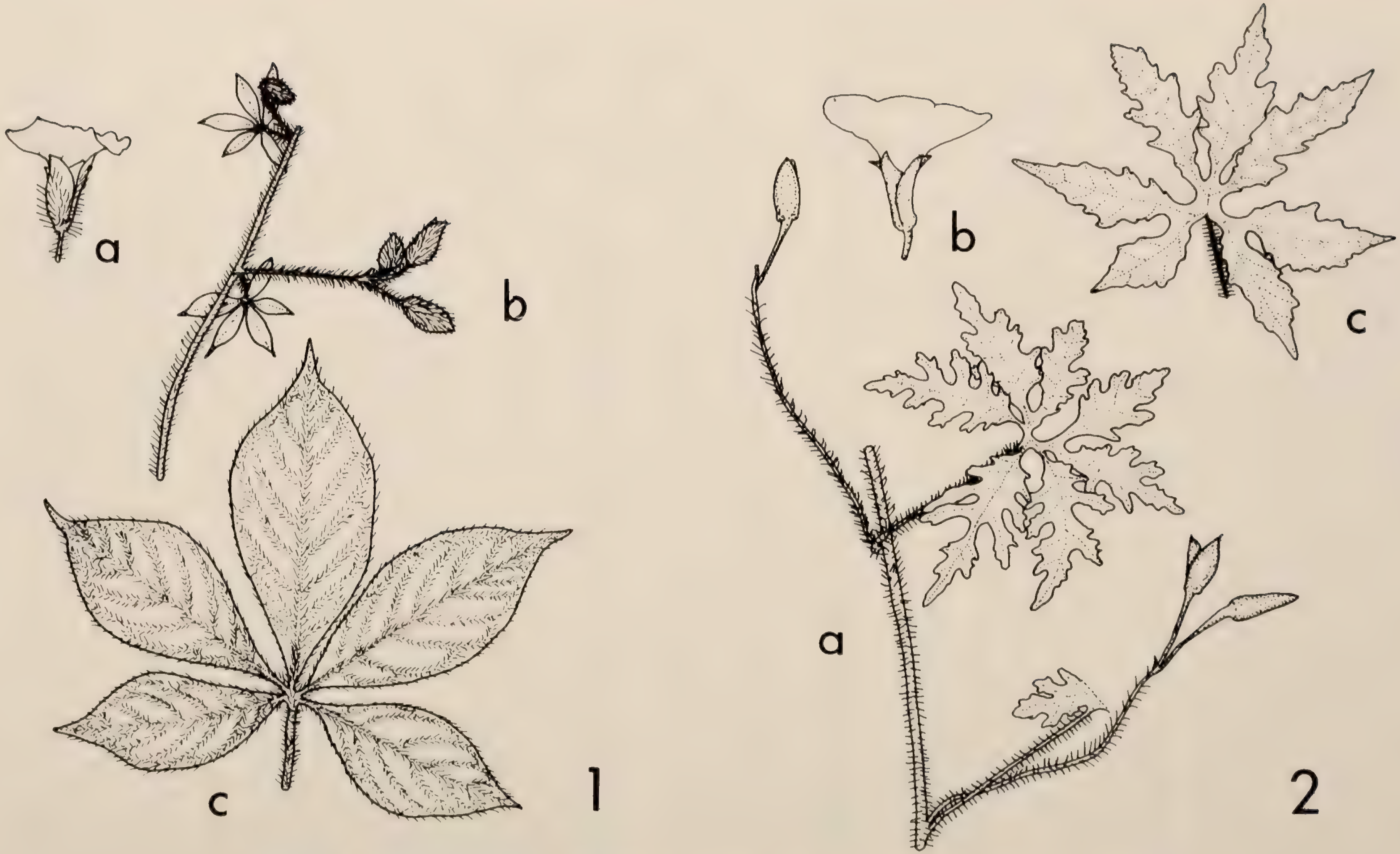
Merremia pentaphylla (L.) H. Hallier, Bot. Jahrb. Syst. 16:552. 1893.

Operculina aegyptia (L.) House, Bull. Torrey Bot. Club 33:502. 1906.

Vines; stems herbaceous, mostly hirsute with long erect to suberect yellowish trichomes. Leaves palmately compound, the 5 leaflets elliptic, entire to dentate, acuminate to acute apically and basally, sparsely pubescent to glabrate. Flowers cymose on long peduncles; sepals oblong, 2 cm long, acute, hirsute with erect yellowish trichomes; corollas white, 2 - 3 cm long. Fruits capsular, subglobose, 1 - 2 cm in dia, subtended and partially surrounded by the calyx; seeds tan, glabrous. Fig. 1.

These are plants of disturbed sites. Not previously listed for the state, the species was collected in Dade County, apparently only once in 1947; ranges from the Bahama Islands and Mexico into South America and the Old World tropics. Flowering from October to December.

Linnaeus originally named these plants *Ipomoea aegyptia* even though he knew they were from the Americas. Apparently he based the specific epithet on the earliest name known to him, *Convolvulus aegypticus* Vesling (Prosp. Alpini Pl. Aegypt. 73. 1640). Later, in 1762, Linnaeus changed his mind and renamed the vines *Convolvulus pentaphyllus*. According to the modern Code of Nomenclature, the original (1753) epithet must be retained.



FIGS. 1-2. Pubescent-stemmed *Merremia* in Florida. Fig. 1. *M. aegyptia.* A-flower, B-habit, C-detail of leaf. Based on Woodbury in 1947 (FAU). Fig. 2. *M. dissecta.* A-habit, B-flower, C-leaf variation. A & B based on Austin 6583 (FAU); C based on Austin 4273 (FAU). All X 1/2.

2. *Merremia dissecta* (Jacq.) H. Hallier, Bot. Jahrb. Syst. 16:552. 1893. Type: grown in Vienna from seeds collected by Jacquin in "America" (no specimen found). Unless the specimen is found, if one was preserved, the plate will be chosen as lectotype.
Convolvulus dissectus Jacq., Obs. Bot. 2;4. *t. 28.* 1767.
Ipomoea sinuata Ortega, Hort. Matr. Dec. 7: 84. 1798. Type: not seen.
Operculina dissecta (Jacq.) House, Bull. Torrey Bot. Club 33:500. 1906.
Ipomoea dissecta (Jacq.) Pursh, Fl. Amer. Sept. 145. 1814. non Willd. (1794).

Vines; stems hirsute to glabrous. Leaves palmately divided almost to base, the 7 - 9 lobes sinuate to crenate, glabrous. Flowers often solitary, occasionally cymose; sepals oblong, 18 - 25 mm long, glabrous; corollas white with purple or reddish center, 3 - 4.5 cm long. Fruits capsular, depressed-globose, 1 - 2 cm in dia, subtended and partially surrounded by the calyx; seeds black, glabrous. Fig. 2.

These are vines of disturbed sites. The species occurs from Monroe to Duval and Levy counties, being also found in the West Indies, Mexico, Central and South America; cultivated and naturalized in Africa, Asia and Malaysia. Flowering from March to October.

This is the common and widespread species in peninsular Florida, and in the coastal plain of Georgia and Texas. The species is easily recognized by the purple throat on the otherwise white flowers.

3. *Merremia quinquefolia* (L.) H. Hallier, Bot. Jahrb. Syst. 16:552. 1893. Type: based on *Convolvulus quinquefolius glaber americanus* Plukenet, Alm. Bot. 116. *t. 167. f. 6.* 1696 (lectotype chosen by Austin, 1975:182).
Ipomoea quinquefolia L., Sp. Pl. 162. 1753.

Lianas; stems usually glabrous. Leaves 5-foliolate, the leaflets subsessile, margins sinuate, serrate or rarely entire, glabrous. Flowers solitary or dichasial; sepals oblong, the outer 3 - 5 mm long, the inner 4 - 7 mm long, glabrous; corollas white, 1.5 - 2.5 cm long. Fruits capsular, subglobose, partially subtended by the sepals, 7 - 8 mm broad; seeds pubescent. Fig. 4.

In Florida known from maturing pineland after disturbance; in more recently disturbed sites elsewhere. The species is also in the West Indies, Mexico, Central and South America. Flowering from December to June.

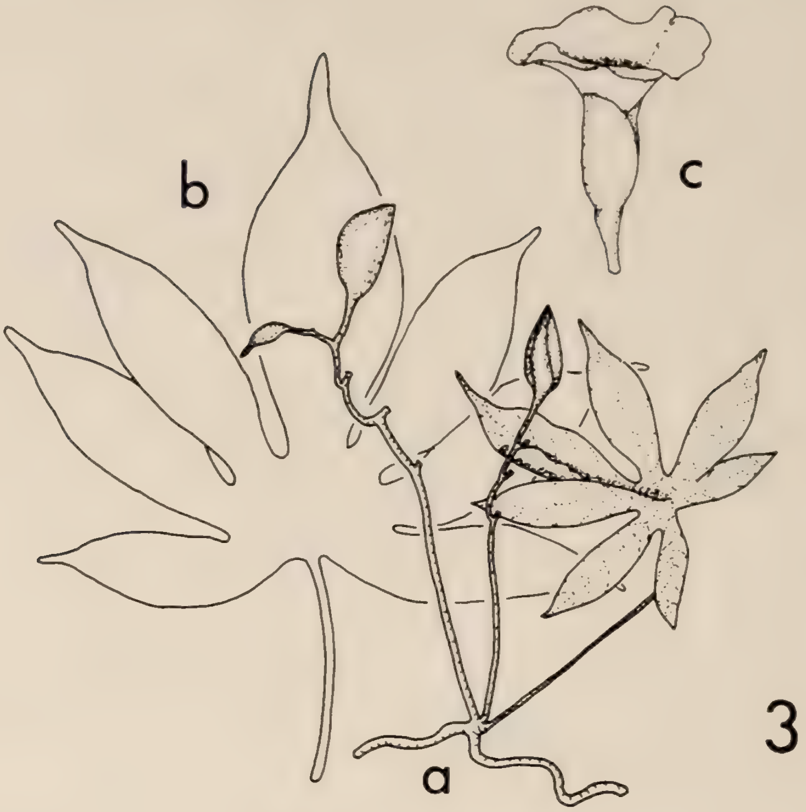
This species was not included in the flora by Small (1933) or by Long & Lakela (1971). From the available data, the plants have been collected twice in Florida. Both collections are from near Biscayne Bay in Dade County. Perhaps this is a native plant but rare; possibly adventive.

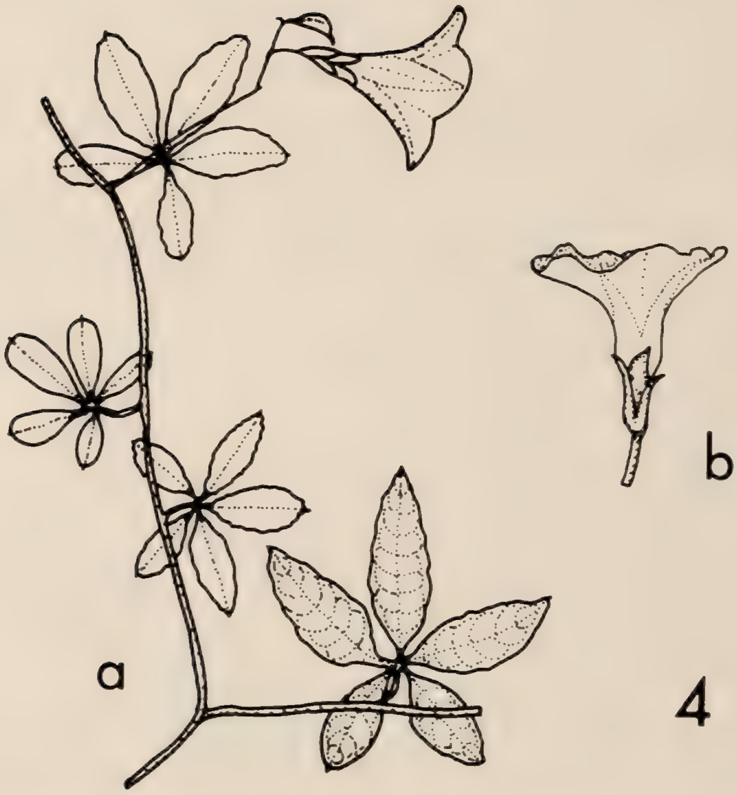
4. *Merremia tuberosa* (L.) Rendle in Thistle-Dyer, Fl. Trop. Africa 4:104. 1905. Type: herb. Linnaeus (LINN 219.4, n.v.; microfiche seen).
Ipomoea tuberosa L., Sp. Pl. 160. 1753.
Operculina tuberosa (L.) Meisn. in Mart., Fl. Bras. 7:212. 1869.

Lianas; stems glabrous. Leaves mostly palmately 7-lobed, margins entire, glabrous. Flowers in compound cymes, rarely solitary; sepals oblong, the outer 25 - 30 mm long, the inner 12 - 30 mm long, glabrous; corollas yellow, 5 - 6 cm long. Fruits capsular but irregularly dehiscent, subglobose, 30 - 35 mm in dia, the sepals accrescent and subtending the fruits; seeds black, densely short tomentose. Fig. 3.

These are high-climbing lianas of hammocks and are persistent from cultivation in most sites; infrequent. Plants are also in the West Indies, Mexico, Central and South American and the Old World tropics. Flowering from November to March, sporadically all year. Wood Rose.

Small (1933) considered these plants to have become naturalized in the Florida Keys although he pointed out that they were widely cultivated. Most, if not all, of the plants now in the state are either cultivated or persisting from cultivation. The plants are native in tropical America, although the exact area is unknown. Yellow flowers and palmately lobed leaves make the species distinctive. This vine is cultivated in at least the southern 5 counties; persisting most often in Dade and Monroe counties.





FIGS. 3-4. Glabrous-stemmed divided-leaved *Merremia* in Florida. Fig. 3. *M. tuberosa*. A-habit, B-leaf outline, C-flower. A & C based on Adams (FAU); B based on Avery 1799 (FAU). Fig. 4. *M. quinquefolia*. A-habit, B-flower. Based on Avery 1423 (FAU).

5. *Merremia umbellata* (L.) H. Hallier, Bot. Jahrb. Syst. 16:552. 1893. Type: West Indies. Haiti. based on Plukenet, Alm. Bot. *t. 167. f. 1.* (here chosen as lectotype).

Convolvulus americanus, vulgaris folio, capsulis triquetris numerosis Plukenet, Alm. Bot. 114. *t. 167. f. 1.* 1696. The specimen forming the basis for this illustration (typotype) is in the Sloane Herbarium.

Convolvulus umbellatus L., Sp. Pl. 155. 1753.

Ipomoea polyanthes Roemer & Schultes, Syst. Veg. 4:234. 1819. Type: based on *C. umbellatus* L.

Vines; stems glabrous or pubescent but glabrate. Leaves entire, narrowly triangular to broadly ovate, pubescent or glabrous. Flowers in sub-umbellate inflorescences; sepals oblong, 6 - 8 mm long, glabrous or pubescent; corollas yellow, 3 - 3.5 cm long. Fruits capsular, 8 mm in dia; seeds dark brown, densely pubescent with short trichomes. Fig. 5.

This species is tolerant of a wide range of conditions throughout its range; in Florida it has been found in disturbed sites. *Merremia umbellata* is also known from the West Indies, Mexico, Central and South America and the Old World tropics. Flowering from October to July.

Small (1933) recorded this species from the Florida Keys. More recently plants have

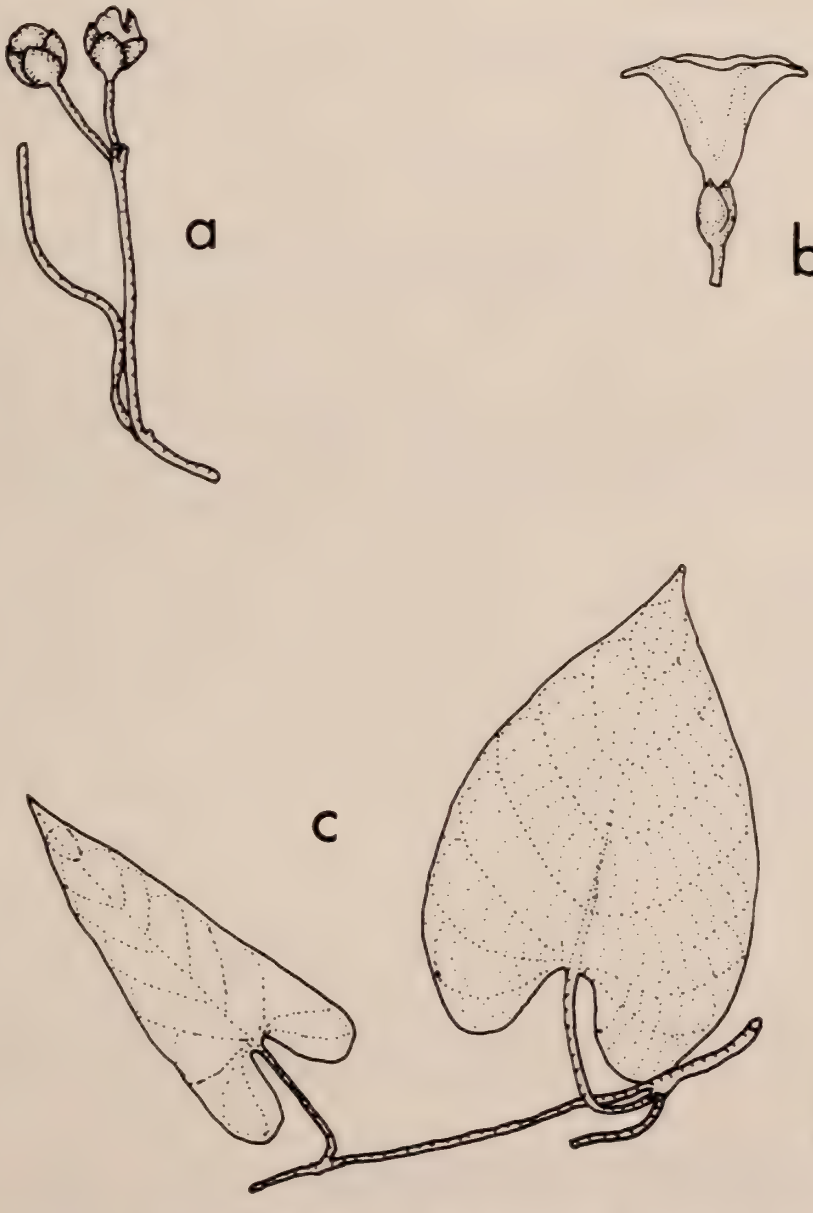


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FIG. 5. Entire-leaved *Merremia* in Florida. *M. umbellata.* A-fruiting branch, B-flower, C-leaf variation. Based on Austin 4456 (FAU). All X 1/2.

been collected in Miami. In the wild it is a rare species in Florida and may not be established in the flora. Plants are occasionally cultivated for their attractive yellow flowers and the vines may escape or persist.

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Florida Sci. 42(4):216-222. 1979.

Biological Sciences

UTILIZATION OF AN INUNDATED FLOODPLAIN BY MISSISSIPPI RIVER FISHES[1]

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Abstract: *The movement of main channel Mississippi River species on an adjoining floodplain was associated with flooding. Of 62 species collected, 24 were characteristic of the main channel and 15 occurred equally in both floodplain or main channel habitats. The presence of juveniles and/or spawning adults indicate that backwaters serve as important nursery areas for riverine fishes.*°

The life cycles of many lower Mississippi River fishes are related to seasonal fluctuations in water levels, particularly the annual flood pattern. When the floodplains are flooded, many fishes migrate from the main channel to the inundated areas for spawning and feeding. These migrations are more lateral usually (i.e., toward and into the inundated floodplain) than upriver or downriver.

Poor land management, however, has drastically changed the natural, inundation cycle of the lower Mississippi River floodplains. With the promotion of drainage schemes under the guise of agricultural and/or urban development, many floodplains have been removed from the influence of the main channel. This apparently has contributed to the decline of the fishery resources of the lower Mississippi River (Gunter, 1952, 1956, and 1957; Viosca, 1927).

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°The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U. S. C. § 1734, this article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

It has been postulated that flooded backwaters of the lower Mississippi River serves as important feeding and nursery areas for main channel fishes. To substantiate this hypothesis, fish collections made on the lower Mississippi floodplain during the 1973 flood are analyzed and discussed in this paper.

STUDY AREA—The study area was located 8 km south of St. Francisville, Louisiana in West Feliciania Parish. The western side of the Mississippi River is leveed, whereas a long line of abrupt Pleistocene bluffs on the eastern side serves as a protective levee. The eastern, natural floodplain is about 2 km wide and is characterized by a backswamp between the higher natural levee of the Mississippi River and the Pleistocene bluffs. The backswamp is characterized by cypress-tupelo gum forests or pastures, dense stands of rooted aquatic vegetation, and mud substrate strewn with organic debris. Several poorly defined channels meander through the swamp and enter Thompson Creek, a tributary of the Mississippi. Even at times of "normal" discharge the shallow backswamp is often inundated by Mississippi River water via lower Thompson Creek. The narrow western floodplain is primarily in pasture interlaced with remnants of former borrow pits.

MATERIALS AND METHODS—Sampling on the inundated floodplain with seine, trammel net, and experimental gill net commenced in February 1973 and continued monthly until July 1973. All 3 gear types were nylon. The seine was 3.0-m by 1.8-m with 0.48-cm mesh. The gill nets were 45.7-m by 1.8-m with mesh size ranging from 2.5-cm to 7.6-cm. Trammel nets were 45.7-m by 1.8-m with 5.1-cm webbing and 25.4-cm outside walls.

Trammel and gill nets were placed on the floodplain in open water parallel to the shoreline. The nets were set just before dark and picked up early the next morning. The number of net-nights (45.7-m of net fished for 24 hr at night) for each net is as follows: gill net—5.5; trammel net—6. Fish collected by net were identified, counted, weighed, and measured in the field.

Twenty-one seine collections were made in shallow shoreline areas of the inundated floodplain. Seining continued in a locality until the "law of diminishing returns" dictated abandonment (i.e., seining continued until new species were no longer taken). Four seine collections were taken monthly in Alligator Bayou, a small floodplain tributary nearby to the above "floodplain" samples, before and after the flood; these data were used for comparative purposes with those from "floodplain" collections. All fishes taken in seine collections were fixed in 10% formalin in the field, later transferred to 45% isopropanol in the laboratory, and then sorted, counted and measured.

RESULTS—A total of 9 species and an average catch of 6.48 individuals and 5.09 kg per net night was taken in gill net samples (Table 1). The most numerous species was the gizzard shad (1.43 individuals per net night) followed by carp and shortnose gar (each with 1.24 individuals per net night). All other species collected yielded less than 0.58 specimens per net night. Carp, with 1.84 kg per net night, contributed the most biomass. Shortnose gar, bowfin, and bigmouth buffalo all ranged between 0.67 and 0.76 kg caught per net night.

TABLE 1. Total catch of seine and catch per net-night of gill and trammel nets on Mississippi River floodplain during the spring flood of 1973. (R denotes species whose center of abundance is in the Mississippi River main channel; B indicates species occurring in both main channel and floodplain habitats).

	Seine		Gill Net		Trammel Net	
Species	No.	%	No.	kg	No.	kg
Spotted gar (B)	5	.10	.57	.36		
Shortnose gar (R)			1.24	.74		
Bowfin (B)	2	.04	.57	.67	1.06	2.36
Skipjack herring (R)	3	.06				
Gizzard shad (B)	154	3.24	1.43	.21		
Threadfin shad (R)	1,275	26.81				
Goldeye (R)	1	.02				
Grass pickerel	16	.34				
Carp (B)	17	.36	1.24	1.84	1.00	2.95
Silvery minnow (R)	746	15.69				
Silver Chub (R)	55	1.16				
Golden shiner (R)	214	4.50				
Emerald shiner (R)	30	.63				
River shiner (R)	98	2.06				
Striped shiner	4	.08				
Pugnose minnow	1	.02				
Ribbon shiner	94	1.98				
Red shiner (R)	7	.15				
Taillight shiner	36	.76				
Silver shiner (R)	70	1.47				
Weed shiner (R)	2	.04				
Blacktail shiner (B)	279	5.87				
Mimic shiner (R)	42	.88				
Bullhead minnow (R)	4	.08				
River carpsucker (R)	11	.23				
Smallmouth buffalo (B)	16	.34				
Bigmouth buffalo (R)	46	.97	.29	.76		
Spotted sucker	4	.08				
Blue catfish (R)	1	.02	43	.30	.16	.15
Black bullhead	14	.24				
Yellow bullhead	182	3.83				
Channel catfish (R)	10	.21	.57	.21	.16	.11
Pirate perch	144	3.03				
Golden topminnow	20	.42				
Starhead topminnow	2	.04				
Blackspotted topminnow	19	.40				
Mosquitofish (B)	357	7.51				
Sailfin molly	5	.10				
Brook silverside (B)	6	.12				
Mississippi silverside (R)	47	.99				
White bass (R)	17	.36				
Yellow bass (R)	6	.12	.14	.01		
Flier	26	.55				
Green sunfish	2	.04				
Warmouth (B)	22	.46				
Orangespotted sunfish (R)	7	.15				
Bluegill (B)	198	4.16				
Dollar sunfish	4	.08				
Longear sunfish (B)	8	.17				

Redear sunfish (B)	44	.93				
Spotted sunfish	25	.53				
Bantam sunfish	39	.82				
Largemouth bass (B)	43	.90				
White crappie (B)	23	.48				
Black crappie (B)	70	1.47				
Banded pygmy sunfish	58	1.22				
Mud darter	3	.06				
Bluntnose darter	8	.17				
Slough darter	12	.25				
Redfin darter	3	.06				
Sauger (R)	9	.19				
Freshwater drum (R)	31	.65			.32	.18
Total			6.48	5.10	2.70	5.75

Shortnose gar, bowfin, carp and bigmouth buffalo were all collected in spawning condition during initial gill net sampling as the river floodwaters first encroached upon the floodplain.

Five species, totaling 2.70 individuals and 5.75 kg per net night, were taken in trammel nets (Table 1). The most frequently encountered fishes were bowfin and gizzard shad with 1.06 and 1.00 individuals, respectively, caught per net night. The other 3 species, blue catfish, channel catfish, and freshwater drum yielded fewer than 0.33 specimens per net night. Gizzard shad, with 2.95 kg per net night, contributed the greatest biomass, followed by bowfin with 2.36 kg per net night.

A total of 61 species was taken in 21 seine collections (Table 1). The most abundant fish was the threadfin shad with 1,275 individuals (26.8%), followed by silvery minnow with 746 (15.7%), mosquitofish with 357 (7.5%), blacktail shiner with 279 (5.9%), and golden shiner with 214 (4.5%). Four species, bluegill, yellow bullhead, pirate perch, and gizzard shad yielded between 100 and 200 specimens.

Species appearing as young-of-the-year or as adults in spawning condition in seine collections included bowfin, threadfin shad, gizzard shad, grass pickerel, carp, silvery minnow, golden shiner, emerald shiner, river shiner, ribbon shiner, taillight shiner, silverband shiner, blacktail shiner, spotted sucker, smallmouth buffalo, bigmouth buffalo, black bullhead, yellow bullhead, mosquitofish, flier, warmouth, bluegill, bantam sunfish, redear sunfish, white crappie, and black crappie.

A total of 62 species was taken in seine and gill and trammel net samples (Table 1). Of these, 39 inhabit the Mississippi River; 23 species are found most commonly in main channel habitats. In seine collections, 83.5% of all individuals collected represent species considered normal inhabitants of the river and 52.9% comprise fishes whose greatest abundance is in the main channel habitats.

The increase in number of species and percent composition of Mississippi River fishes in floodplain seine collections in association with rising water levels is evident from Fig. 1. The number of characteristic Mississippi River fishes remained low on the floodplain (< 12 species) until it was flooded and the number of river fishes increased to a peak of 32 species in July. The percent composition of river fishes illustrated a similar trend. As discharge decreased and the flood waters receded both the number and percent composition of river fishes decreased.

Species unknown from floodplain habitats prior to the flood included skipjack herring, threadfin shad, goldeye, silver chub, emerald shiner, river shine red shiner, silverband shiner, weed shiner, mimic shiner, bigmouth buffalo, blu catfish, channel catfish, Mississippi silverside, white bass, yellow bass, orangespotted sunfish, sauger, and freshwater drum.

Discussion—It was not possible to determine the origin of fishes collecte on the inundated floodplain which are characteristic of both floodplain and mai channel habitats. Therefore, the assumption was made that species considere as normal inhabitants of the main channel were derived from river population in order to determine the degree of dominance of such species on the inundate floodplain. This is a valid assumption because during periods of low discharge the magnitude of aquatic habitats on the floodplain is insignificant when compared to that available in the Mississippi River.

During spring floods, Mississippi River fishes apparently migrate laterally, o perpendicular to the direction of flow, into adjacent floodplains, thus enablin them to move into quiet backwater habitats. This is illustrated by the predominance of Mississippi River fishes on the inundated floodplain. The presence o large numbers of juveniles and adults in spawning condition of many riverin

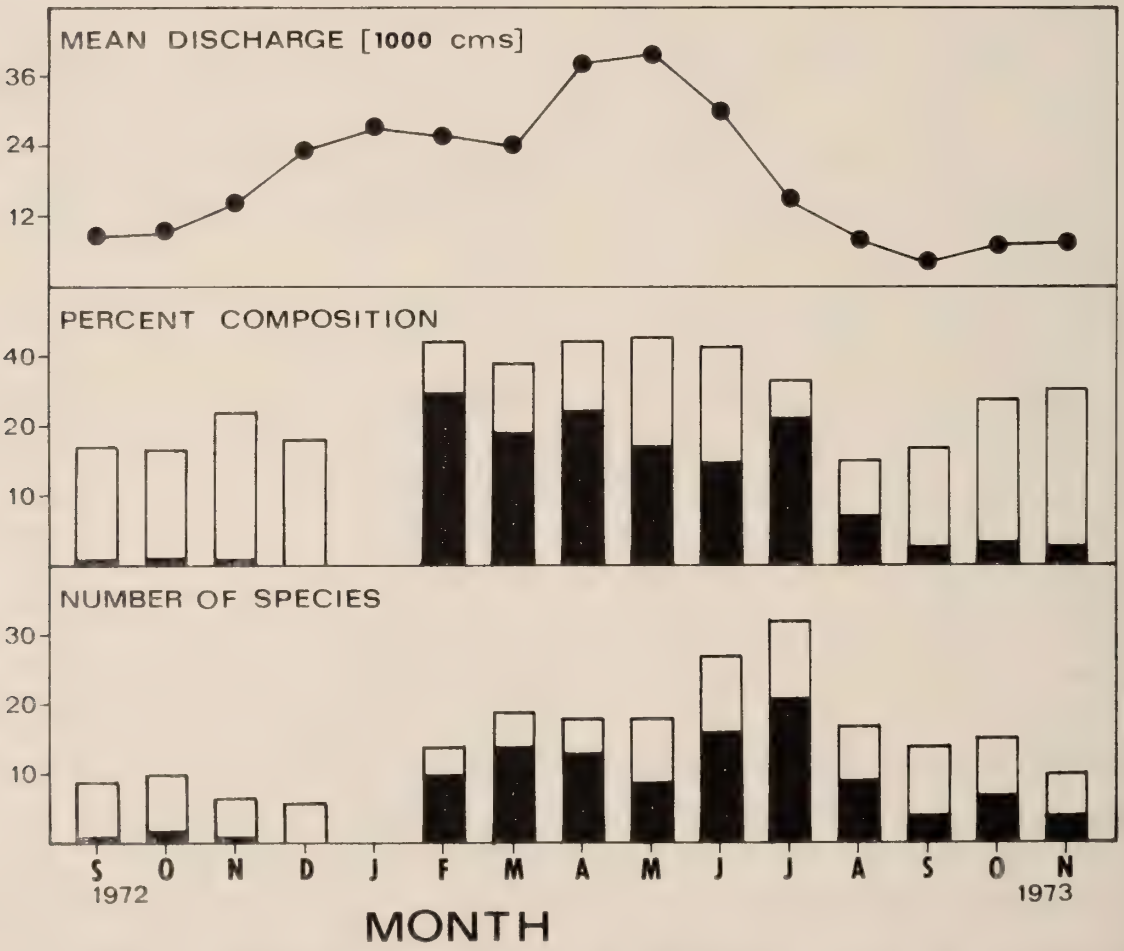

Fig. 1. Monthly variation in mean discharge and in number of species and percent composition of common Mississippi River fishes in floodplain seine collections. Darkened portion denote species which occur most abundantly in main channel habitats.

species shows that many of these fishes utilize the floodplain as a nursery area. Also obvious is the movement of riverine fishes out of the floodplain back into the Mississippi River main channel where they contribute to the recruitment of fish populations in the main channel. However, entrapment of these river fishes in floodplain sloughs by rapidly dropping water levels is evident by the continued presence of riverine fishes in floodplain seine collections.

Fish movement into and out of backwaters and floodplains in response to water level fluctuation has been studied by several workers. Shapp (*in* Christenson and Smith, 1965), in his study of fish movements into a previously dry rearing pond adjacent the Mississippi River, found that 140 kg per ha had entered the pond in 2 wk. Christenson and Smith (1965) suggested that backwaters are apt to be invaded as soon as suitable conditions are reestablished. Falling water levels were accompanied by movement of several species out of backwaters in pools 8 and 9 of the upper Mississippi River (UMRCC, 1947). Johnson (1963) concluded that the stimulus that caused the spawning migrations of the bigmouth buffalo was the spring inundation of floodplains. Paddlefish have been observed migrating laterally into Mississippi River oxbow lakes in association with rising water levels (Stockard, 1907).

Christenson and Smith (1965) and Schramm and Lewis (1974) reviewed factors associated with the high nursery capabilities of flooded backwaters. Included were soil fertility, reduced current velocities, food availability, and water level fluctuation. The lower Mississippi River main channel, characterized by high current velocities, high levels of turbidity, absence of aquatic vegetation, and unstable sandy substrates, is not as productive as is floodplain habitats, typified by slackwaters, heavy stands of aquatic vegetation, and fine, organically rich substrates.

Fish production is related to the extent of backwater or floodplain development. Richardson (1921) found an average fish yield of 199 kg per ha in a section of the Illinois River with about 90% of the acreage consisting of backwater, 146 kg per ha in those areas with about 83% backwaters, and 78 kg per ha in sections with 63% backwaters. Barnickol and Starrett (1951) noted a reduction in game fish in a section of the Mississippi River with reduced backwater areas. Where adjoining backwaters along the lower Colorado River were drained, there was a 100% reduction of fishery values (Beland, 1953). Lambou (1963) showed that the most productive sport and commercial fisheries in the Atchafalaya Basin were located in those areas containing the greatest amount of backwaters.

Obviously floodplains serve an important role in the perpetuation of riverine fisheries; however, little effort has been exerted toward the preservation of floodplains along large rivers. Any physical destruction of floodplains, or any manipulation which hinders access to these habitats, could have an adverse impact on the fishery. Because the primary goal of fish management is the sustained yield of sport and commercial fisheries, protection, or even restoration, of floodplains should be a top priority in any management program for large rivers.

Acknowledgments—Gulf State Utilities provided financial support for this study. I thank Louisiana State University for administering the project, Charles Bryan and Van Conner for guidance, and many fellow graduate students who aided in sampling.

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Florida Sci. 42(4):222-228. 1979.

Biological Sciences

REPRODUCTIVE BIOLOGY OF *NEMASTYLIS FLORIDANA* SMALL (IRIDACEAE)

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Abstract: *Field studies of* Nemastylis floridana, *commonly known as Celestial Lily, a rare endemic of the moist flatwoods of east-central Florida, were conducted to determine its breeding ystem, pollen vectors, phenology and germinative capacity. The chief pollinators were* Augochlorella triata *and* Evylaeus foxii *(Halictidae). The flowers were found to be self-compatible. Self-pollination occurred without an outside vector, although this resulted in lower seed set. The pollen-ovule atio was 690 and the outcrossing index was 3. This agreed well with Cruden's data for facultative enogamous species. All seeds obtained from experimental plants germinated and grew readily when lanted in pots and kept moist. The scarcity of* Nemastylis floridana *is probably due to environmental auses rather than to reproductive ones.*[*]

The threatened (Ayensu and De Filipps, 1978) endemic, *Nemastylis floridana* Small, is a bulbous member of the Iridaceae with plicate leaves which inhabits noist flatwoods of east-central Florida. Collections from 10 herbaria range from Flagler to Broward County (Fig. 1) but approximately two thirds of the specinens are from Brevard and Volusia Counties. The 4 other species of *Nemastylis* are native to the south-central states and Mexico (Goldblatt, 1975). We wanted o determine the reproductive biology of this species and to see if any phase of ts biology could account for the rarity of the species.

Materials and Methods—The population of *Nemastylis floridana* used in his study is located off Highway 44, east of DeLand at the Volusia County Stulent Bicentennial Park. The habitat is wet pine flatwoods. The soil is sandy and acidic (pH 6) and is characterized by a semi-impervious hardpan 1-2m below the urface. Species associated with this habitat include *Pinus elliotii Engelm.*, *Serenoa repens* (Bart.) Small and *Ilex glabra* (L.) Gray. Charred bark on the pines ndicated that the area had been exposed to fire. The plants were distributed over 50 ha in the moister situations and were usually growing in groups of up o about 30 individuals.

Data were gathered from 1 September-7 December 1977. Data collected ncluded floral phenology and morphology, time of floral opening and closing, eed and capsule maturation and later, seed viability.

Experiments to determine the reproductive pattern of *Nemastylis floridana* were conducted using 93 randomly selected flower buds divided into 6 groups: 1) A set of buds was tagged and left uncaged as controls. 2) To test for selfcompatability, buds were caged, self-pollinated by hand when the flowers opened

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[*] The costs of publication of this article were defrayed in part by the payment of charges from funds made available in support of the research which is the subject of this article. In accordance with 18 U.S.C. 1734, his article must therefore be hereby marked "*advertisement*" solely to indicate this fact.

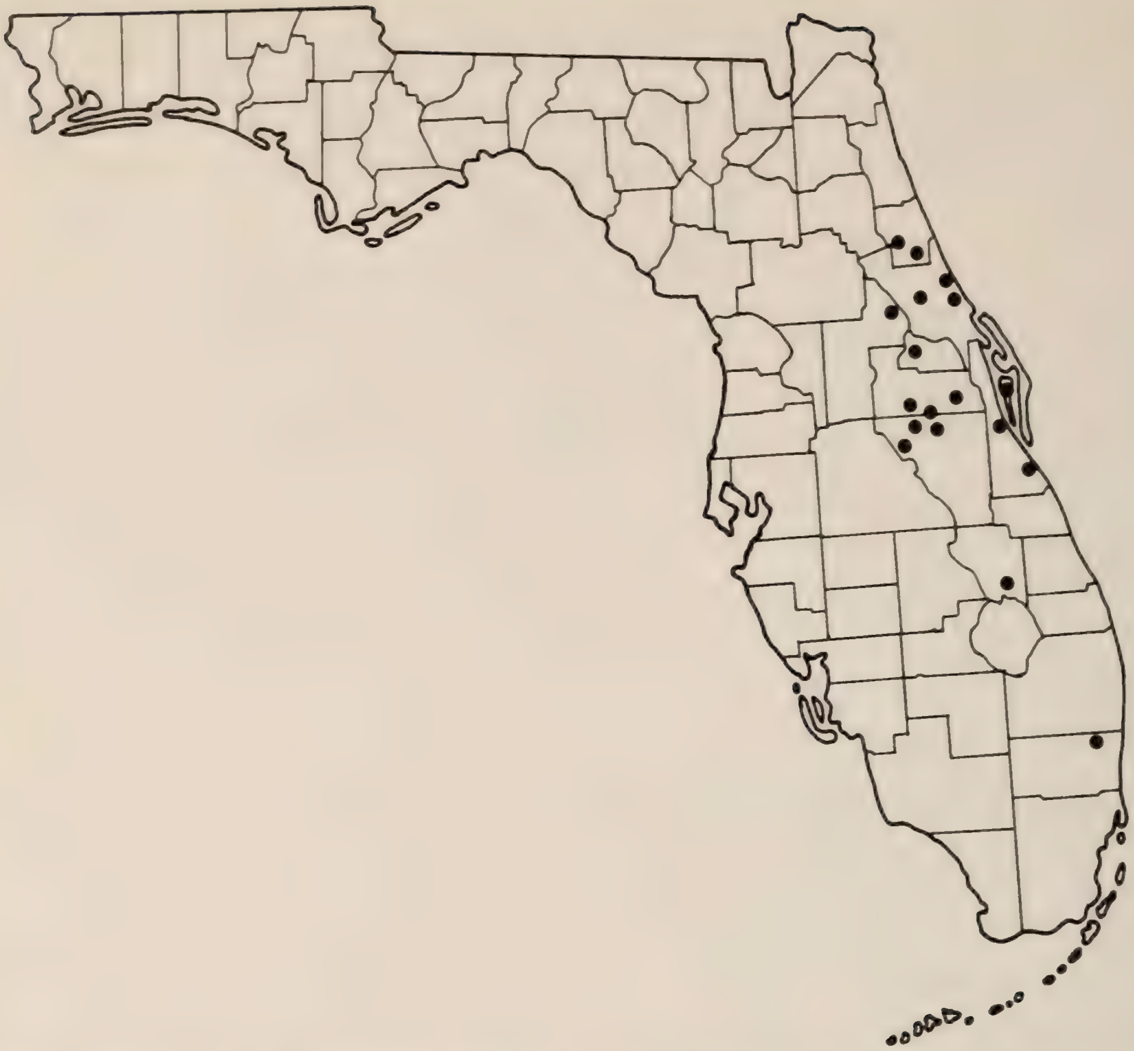

Fig. 1. Distribution of *Nemastylis floridana* based on collections from the following herbaria: DLS, FLAS, GH, ILL, MO, NY, SMU, TEX, US, and USF (Holmgren and Keuken, 1974).

and recaged. 3) Self-pollination was tested by caging buds and leaving the cages on until the flowers withered. 4) Buds were emasculated and left caged to test for apomixis. 5) Petals, sepals and stamens were removed from large buds and left uncaged as a test for possible wind pollination. 6) Finally to test for cross-compatibility, buds were emasculated before anthesis and the stigmas were dusted with pollen from distant members of the population and recaged. The cages were made of light nylon netting with pores less than .5mm in dia and drawstrings at top and bottom. Within 1 to 2 da after anthesis, if fertilization had occurred, a small green capsule could be seen developing.

Insects visiting the flowers were observed and representative ones were collected. Their behavior was noted and they were later checked for pollen. All insects collected were identified by E. E. Grissell. In addition to these observations and experiments, pollen to ovule ratio (P/O) and outcrossing index (OCI) were determined as indicators of possible breeding system as described by Cruden (1977). The number of ovules per flower was determined through repeated counts with hand lens and dissecting microscope. To determine the number of pollen grains per flower, one half of an anther was shredded with a dissecting needle in 2 ml of aniline-blue in lactophenol. Using a Sedgewick counting cell and a compound microscope, the number of pollen grains in one half an anther was found and multiplied by 6 to give the total number of pollen grains per flower. This procedure was repeated 3 times with anthers from 2 different flowers and a mean number of pollen grains per flower was determined. Cruden's OCI was computed by assigning values to 3 floral characteristics as follows: 1) diameter of corolla-(< 1mm = 0; 1-2mm = 1; 2-6mm = 2; > 6mm = 3°). 2) temporal separation of anther dehiscence and stigma receptivity-(homogamy and protogyny = 0°, protandry = 1). 3) spatial relationship between stigmas and anthers-(contact possible = 0°, contact impossible = 1). The values assigned to *Nemastylis floridana* are starred.

The apparent breeding system, P/O and OCI were then compared with Cruden's data (1977).

Results—*Plant morphology and phenology.* The bulb of *Nemastylis floridana* s ovoid and approximately 1.5 cm in dia occurring at a mean depth of 4.5 cm below the surface. Leaves of the plant are plicate-linear attenuate and primarily basal. The stems are slender, 90-100 cm in length, and dependent on surrounding vegetation for additional support.

The flowers occur in pairs in a branching inflorescence. The first flower to mature of the pair is subtended by a spathe approximately 2 cm in length and s located slightly more distally than the later blooming flower which is subtended by a small spathe. In cases where the upper flower opens much earlier than the lower flower, the upper capsule may become quite large before the second flower begins to open. This large capsule seemed in some cases to prevent the second flower from opening completely and thus possibly inhibited pollination. A random sampling showed that most plants had an average of 8 flowers (4 pairs) during a season. Of these 8 flowers, 6 produced capsules. Four of these capsules occurred in 2 pairs, while the remaining 2 capsules occurred singly. In the artificially pollinated groups, the second flower was removed to prevent confusion with the flower being tested.

The actinomorphic perianth is deep violet in color with the exception of a small central white eye. There are very fine darker purple striations radiating from the center. These are presumably the black flecks noted by Small (1931). The perianth measures approximately 3.5 cm in dia. Sepals and petals are elliptic with the sepals measuring 1.8-2.0 cm in length and the petals 1.4-1.6 cm in length.

The 3 stamens consist of filaments 2mm in length united at the base and supporting long erect anthers approximately 0.8-1.0 cm in length. As pollen is released the bright yellow anthers curve inward and twist in a spiral fashion. Dehiscence apparently begins just prior to or simultaneously with the opening of the flower. In a few cases pollen was noted on the tepals of freshly opened flowers. Pollen grains 53 μm by 18 μm were elliptic and monocolpate.

The style branches at the apex of the filaments and the branches are almost at right angles with the axis of the flower with pairs of branches alternating between each anther. The style is translucent white at the base and increases gradually in color to violet at the papillose terminal stigmatic surfaces. The ovary contains 48 ovules on the axile placentas. Flowers lack a discernible scent and nectar is not produced.

Flowers were found in anthesis in this population from 1 September-20 November. The flowers opened at 2:30-3:00 p.m. (EST). Buds due to open on a particular day begin to show color by noon. Flowers begin to close around 6:00-7:00 p.m., closing earlier as the days become shorter.

A bright green capsule develops if fertilization has occurred. As the seeds mature, a bright yellow protrusion originating from the area near the funiculus becomes apparent. If the seed is punctured a viscous yellow liquid exudes from the protrusion. Tests with I_2KI showed that the liquid was high in starch. Tests with Sudan IV were negative for fatty substances and the liquid was not bitter to the taste. Immature seeds are bright green except for the yellow protrusion which sometimes may be seen through the capsular wall. As the seeds mature the yellow liquid dries up and shows as a slight dark area on the surface of the yellowish-brown propagules. At maturation the upper portion of the capsule splits radially through the center of each locule and becomes reflexed allowing seeds to fall out. Seeds may begin to be dispersed 4 wk after flowering.

In December seeds from all the experimental groups were planted in moist flatwood soil. They all began to germinate 2 wk after planting.

Flower foragers and pollinators: Four species of bees were observed and collected while visiting our plants. *Bombus pennsylvanicus* (Degeer) visited several species of flowers in the area and made short visits to *Nemastylis floridana*. These large bumble bees dragged the fragile flowers to the ground. Pollen grains similar to those of *Nemastylis floridana* were found in the bee's pollen baskets.

Agapostemon splendens (Lepeletier) visited the flowers but no pollen was found on the specimens. This was the largest of the 3 species of halictid bees visiting the flowers and was usually observed clasping an anther or resting in the central area of the flower.

Two other halictid bees, *Augochlorella striata* (Provancher) and *Evylaeus foxii* (Robertson), were the most common visitors to the flowers. The first of these was an especially voracious gatherer of pollen. It could often be found visiting a flower almost immediately after its opening. This bee began working each anther from the top to the base. Pollen was gathered rapidly and pushed with the forelegs over the ventral abdomen into pollen baskets on the hind legs. After working one anther the bee would go to another anther on the same flower and was occasionally observed to contact the stigmas. After having been worked by one of these bees, little or no pollen could be shaken from the anthers. The pollen found in the pellets from the bee's hind leg appeared to contain only pollen from *Nemastylis floridana*.

Evylaeus foxii is a much smaller bee and more difficult to observe. Although it was a frequent visitor to the flowers, it did not completely strip the anthers of pollen as did *Augochlorella striata*.

The bees appeared to be attracted to *Nemastylis* exclusively by sight. Insect activity was most frequent on warm days from 3 to 4 p.m. Grasshoppers fed on immature capsules and seeds. Some flower buds appeared chewed but the source of depredation was not discovered.

Experimental studies: Experiments on the breeding system indicate that

Nemastylis floridana is self and cross-compatible (Table 1) with no indication that wind pollination or apomixis could occur. Although the sample is small, it is clear that both outcrossing and selfing are possible. The former condition produces slightly more seeds. In nature, self-pollination is probably more common than xenogamy, judging from the insects' behavior. Direct autogamy without insect vector is also possible. However, enclosed flowers only produced fruits 20% of the time and each capsule had fewer seeds than did the control population.

The average number of pollen grains per flower was determined to be 33,120. The number of ovules per flower was consistently 48. The P/O was 690. The Outcrossing Index as described by Cruden was 3. These results would place *Nemastylis floridana* in his Class 4 which consists of facultative xenogamous species. He characterizes these plants as being "regularly self-compatible and protogynous or homogamous. Although some species require a pollinator, most self-pollinate when the flowers close. Even though selfing may occur it is clear that the adaptations favor xenogamy and that selfing occurs in the absence of, or in addition to outcrossing." This is a good description of the breeding system in *Nemastylis floridana*, although perhaps it might be better characterized as intermediate between facultative xenogamy and facultative autogamy. Further experimentation would be required to determine the amount of self-pollination versus cross-pollination. It is worth noting here, however, that in *Iris tenax* (Smith and Clarkson, 1956) the pollen tubes' growth after cross-pollination was significantly faster than after self-pollination. Grant (1975) points out that, although it would seem from the bees' activity that self-pollination might be more frequent than cross-pollination in certain species, that one can make no inference from this as to whether the resulting progeny will be primarily inbred or outbred.

The reasons why columns 2 and 4 (Table 1) do not match exactly is because some fruits were eaten by grasshoppers before we had a chance to count seeds or because some fruits started dehiscing before we had an opportunity to examine them.

DISCUSSION—Experimentation indicates that *Nemastylis floridana* is cross- and self-compatible and is primarily dependent on an entomophilous mode of pollination, although selfing did occur occasionally. The specific mechanism of self-pollination is not clear. Pollen grains were occasionally noted on the tepals of flowers and as the tepals close these grains may come in contact with stigmatic surfaces. Also, as pollen dehisces from the stamens, the anthers curve inward and could come in contact or shed pollen on the stigmatic surfaces. Molseed's study (1970) of the related genus, *Tigridia*, revealed that many of the species are self-compatible and produced seeds when hand pollinated. However, among the 7 self-compatible species, he found that only in the cultivated form of *Tigridia pavonia* self-fertilization occurred without a vector. His results were based on greenhouse conditions. It may be that further observations will show that in *Tigridia* as in *Nemastylis* selfing can occur but does so infrequently.

Goldblatt (1975) indicated that this species, in fact a sample from this population, is a polyploid with 2n = 56. It is thus possible that self-compatibility in

TABLE 1. Breeding experiments with *Nemastylis floridana*.

Item:	Number	Number Flowers Setting Fruit	Percent Flowers Setting Fruit	Number Mature Capsules Collected	Number Seeds per Capsule and Average
Control	24	17	70.8	17	12–30, 19.0
Self-compatibility	14	12	85.7	6	15–38, 19.2
Self-pollination	20	4	20.0	2	16–17, 16.5
Apomixis	11	0	0	0	0
Wind pollination	14	0	0	0	0
Cross-compatibility	10	9	90.0	7	18–29, 22.4

in *Nemastylis floridana* is due to polyploidization (Grant, 1971). However, it seems likely judging from Molseed's work on *Tigridia* (1970) and from knowledge of the breeding system of the other related genera of the Iridaceae (Goldblatt, pers. comm.) that *Nemastylis* may be basically a self-compatible genus.

In conclusion, the breeding system of *Nemastylis floridana* is not responsible for the plant's scarcity and rather restricted distribution. The plants flower prolifically and produce an abundant quantity of seeds. The pollinators are not uncommon and are apparently available throughout the season. The plant's scarcity must be sought elsewhere.

The means of seed dispersal is not completely apparent. Seeds are probably moved by water and perhaps by ants. We placed some seeds in an area where they could be observed and saw some ants attempt to move them. Several hours later the seeds were gone although we never actually observed their movement.

Cold temperatures may inhibit the distribution of the species northward. One pot with young seedlings exposed to near freezing temperatures in January and February 1978 showed damage. Even the seedlings that survived remained stunted. Of course, once a plant is established with a well developed bulb, cold temperatures would not be as severely limiting.

Man may limit the abundance of *Nemastylis floridana* through destruction of habitat. Drainage of flatwoods depletes the water supply necessary for its growth. Plowing and filling of flatwoods are also undoubtedly detrimental.

Fire is beneficial to many species of the flatwoods community and it was obvious that the site of our study had been exposed to fire several years previously. Fire may help in eliminating competition for space and light. The suppression of ground fire may also be partially responsible for the plant's scarcity. The natural succession of low flatwoods leading to bayhead communities (Laessle, 1942) would also lead to the elimination of *Nemastylis*.

It is also possible that the plant is not as scarce as the collections indicate. The plant's late afternoon blooming habit may have caused it to be overlooked especially in the area between Brevard and Broward counties which have not been botanized extensively.

ACKNOWLEDGMENTS—We are very grateful to Dr. Peter Goldblatt, Missouri Botanical Garden, for providing encouragement, distribution data and much valuable information. We also appreciate the help of E. E. Grissell, formerly of the University of Florida for identification of the bees and that of Paul Bishop, director of the Bicentennial Park for ensuring that our plants were not molested.

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Earth Sciences

A RESIDUAL MAGNETIC ANOMALY MAP FOR ALACHUA COUNTY, FLORIDA

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ABSTRACT: *Three hundred and seven measurements of the magnetic field with a proton precession magnetometer in Alachua County, Florida, yielded total intensity values of 50,067–51,035 gammas. All values were tied to a single base station and were corrected for diurnal variations. A regional trend reveals a westward dip of approximately 30 gammas/km and may reflect the flank of the Florida Peninsular Arch. Removal of the regional trend from an isomagnetic surface isolates residual magnetic anomalies ranging from –40 to 120 gammas. Interpretations of the local anomalies suggest mafic dikes and horizontal susceptibility contrasts within the Paleozoic basement rocks of north Florida. These features are consistent with previous concepts of diabase intrusions and graben structures which originated in the Florida basement during the early Mesozoic.*[*]

COMPILATIONS of magnetic field values for Florida were first presented by Lee et al. (1945) as a series of east-west traverses across the Florida peninsula. King (1959) incorporated these and other early data in a regional magnetic anomaly map of Florida with contour intervals of the vertical component placed at 100 gammas in order to emphasize broad features. The anomalies, based on an arbitrary datum, ranged from 400-1700 gammas. In general, two dominant trends, a well-defined northeasterly trend in the northern half of the peninsula paralleling structural patterns in the southern Applachians and a northwesterly trend in the southern part of the peninsula, are displayed by the anomaly contours. A separate pattern of magnetic anomalies occupying a wide belt across the central part of the Florida peninsula has been attributed to buried volcanic rocks (Gough, 1967). Gough mapped magnetic anomalies on the west Florida shelf and described them as indicative of a continuation of the subsurface volcanic province which he estimated to be at least 9 km deep.

As the contribution to regional magnetic anomalies from the thick sedimentary rock sequences overlying the Florida basement is probably negligible, the anomaly patterns and values can provide significant information concerning the nature of the basement rocks. The statewide survey of King (1959) reveals only regional anomaly patterns because of its composite nature and inherently large contour intervals. We present results from a detailed survey of the total magnetic field intensity in Alachua County, Florida. The survey, conducted during the spring and early summer of 1978, consists of values recorded at 307 separate stations. The research was initiated to identify local anomalies, compare their trends with regional anomaly patterns, and provide additional information with which to evaluate the basement rocks. A complete account of the data is given by Bennett (1978).

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METHODS—All measurements were made with a GeoMetrics G-816 portable porton precession magnetometer. The proton precession magnetometer operates by passing an electric current through a liquid, which generates a magnetic field. When this current is suddenly removed, the protons in the liquid precess in unison about the earth's magnetic field, including a voltage at a precession frequency which is directly proportional to the magnetic field intensity.

A base station was established at the University of Florida Horticultural Unit, about 5 km northwest of Gainesville, Florida. Baseline observations were made at the base station on 2 successive da at 30 min intervals for 5 hr periods to obtain representative diurnal variation curves. A datum level of 50,875 gammas was chosen as a representative base station value for later calculation of relative magnetic intensities. The effects of the diurnal variation on the individual field stations were removed by reoccupation of the base station at 2-3 hr intervals. Daily plots of variation vs. time were then constructed, and field station values were adjusted accordingly. Ten to 25 field station values were occupied during a typical field day. All stations were reached by automobile and were located on a county road map to within 0.16 km. Coverage is less complete in the eastern portion of the county because several large areas have no public access.

Individual measurement sites were selected for magnetically clean environments. Readings were made at least 18 m from automobiles, pipelines, and culverts, and at least 11 m from low power lines and buried telephone cables. At each field location, at least 5 measurements were made, with a usual repeatability of ±2 gammas. Minor flucturations in the magnetic field probably occurred between successive reoccupations of the base station. Dobrin (1976) estimates such fluctuations to be on the order of ±10 gammas over a 3 hr period. The maximum error accepted at any field station, as determined by repetitive measurements, was ±5 gammas. The maximum cumulative error is thus ±15 gammas for any one field value.

Although the base station was centrally located, it was difficult to reoccupy within reasonable times from more distant parts of the county. Therefore, 2 substations (Fig. 1) were established as reference points for nearby field stations.

RESULTS—A total-field isomagnetic map (Fig. 1) for the county was interpolated using data from the 307 field stations. Individual values were adjusted

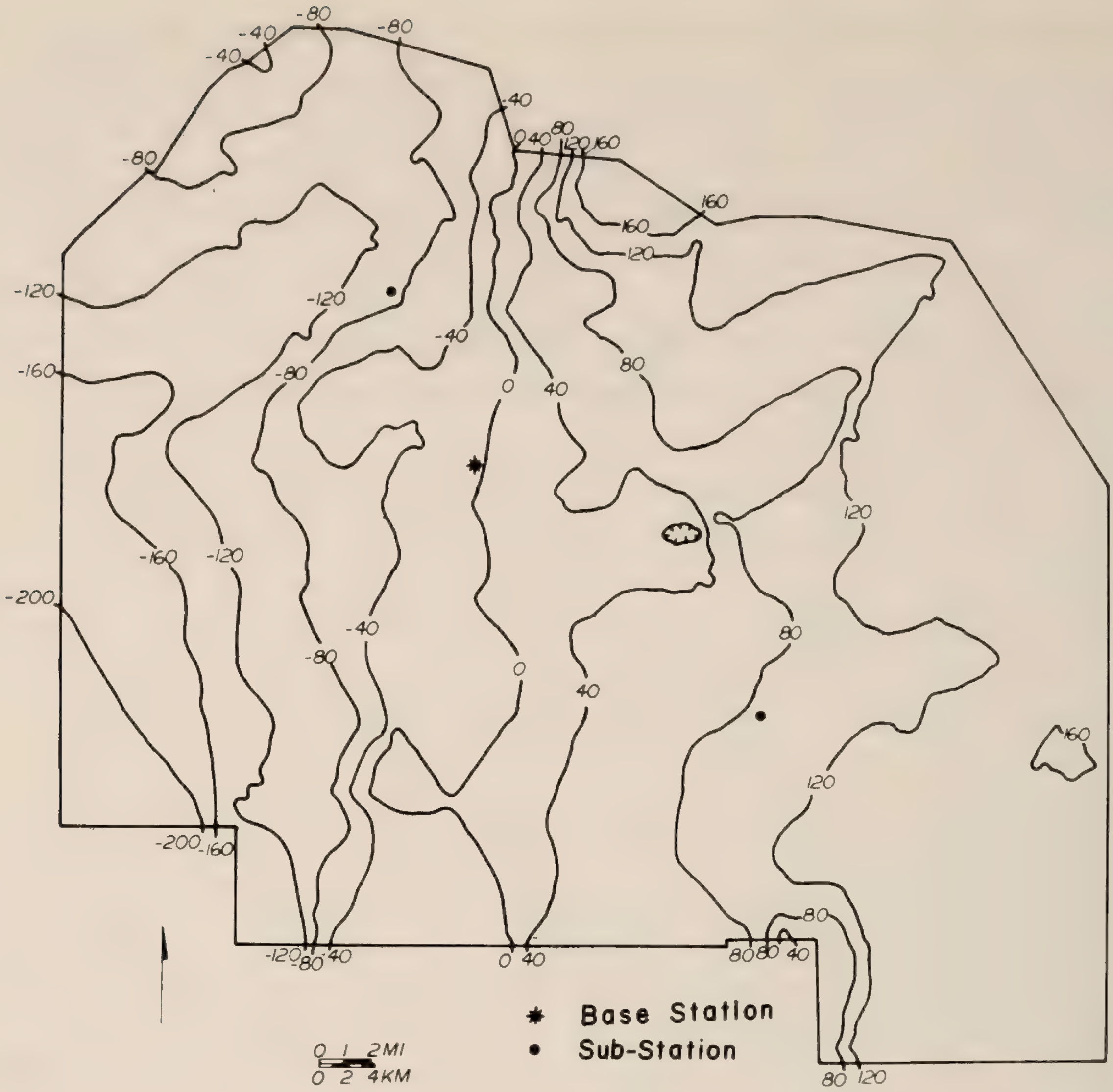

Fig. 1. Computer-derived isomagnetic map of Alachua County, Florida. Values are in gammas.

to remove the effects of diurnal variations, but the regional gradient has not been removed. This map, constructed with a SYMAP computer graphics program (Dougenik and Sheehan, 1975) illustrates the total intensity of the earth's magnetic field, including local fields superimposed over the main field.

A second-order trend surface, represented by a series of convex arcs trending from high values in the eastern portion of the county to low values in the western portion, was constructed by computer for the isomagnetic values. This trend surface is analoguous to a regional gradient for the magnetic data; thus, broader anomalies indicative of deep, large-scale sources or internal magnetic field variations are included with it. A residual anomaly map (Fig. 2) was constructed by removing the second-order trend surface from the isomagnetic map. The residual anomaly map depicts magnetic anomalies representing shallow, local sources.

Discussion—The isomagnetic map produced by interpolation of the 307 corrected field values reveals 2 major trends (Fig. 1). A regional gradient of about 30 gammas/km trends east-west from high values (120-160 gammas) in the eastern portion of Alachua County to low values (–160 to –200 gammas) in the western portion. This pattern is particularly evident in the southwestern

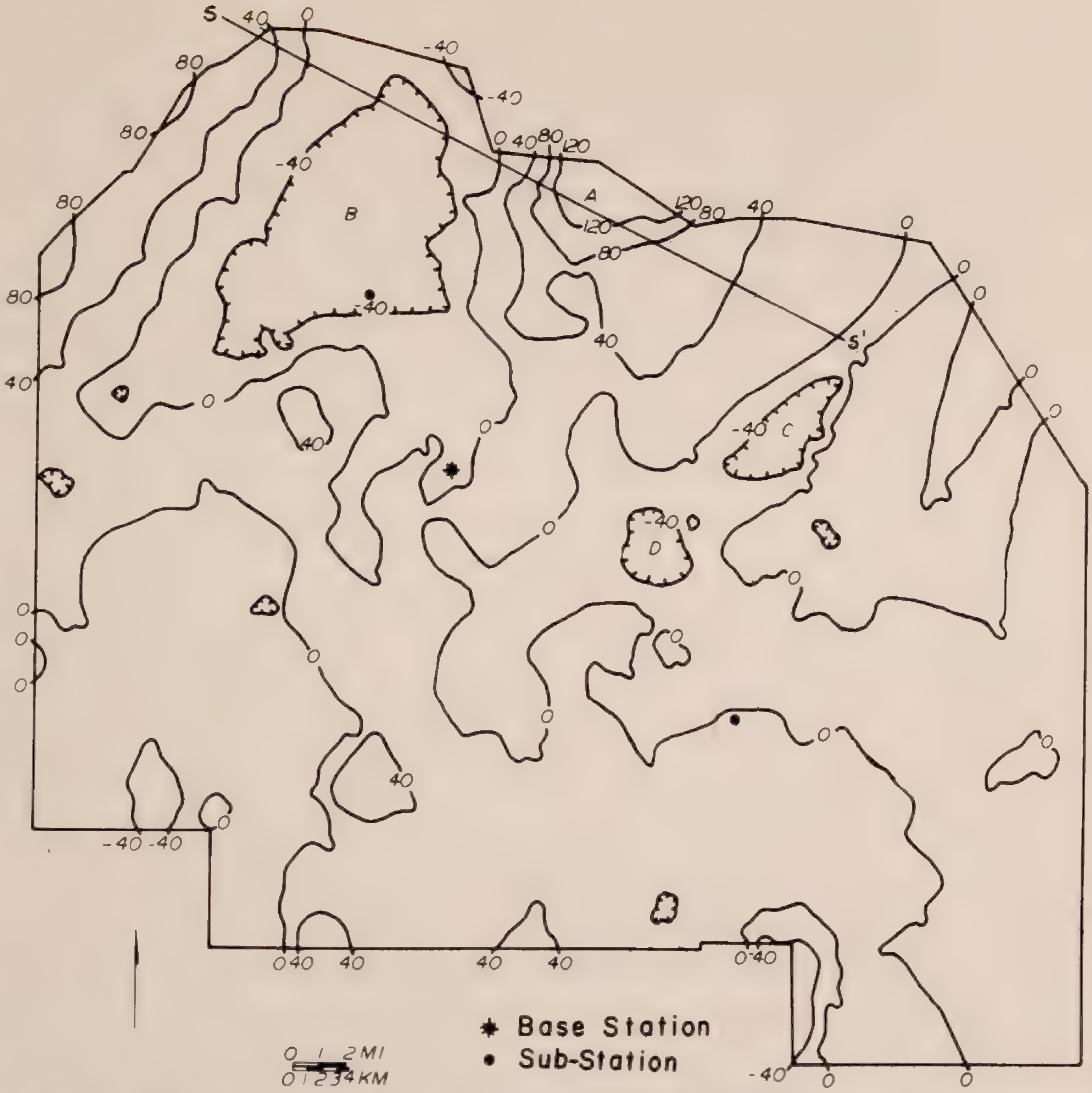

FIG. 2. Residual anomaly map generated by removal of a second-order trend surface (regional gradient) from the isomagnetic surface of Fig. 1. Values are in gammas. A, B, C, and D refer to anomalies discussed in the text. Line S-S' depicts the profile path for Fig. 3.

part of the map, where data coverage was most complete. Lee et al. (1945) mentioned a similar east-west regional gradient in Alachua County. Other workers, including King (1959), removed the regional gradient without discussing it. The decrease in high magnetic values from the eastern edge of Alachua County toward the west may reflect an increasing depth to the magnetic basement rocks which form the Peninsular Arch. A second pattern of northeast-trending contours appears in the northwest corner of the county.

The regional gradient has been removed in the residual anomaly map (Fig. 2). An excellent correlation exists between the northeasterly trend of the anomalies in Fig. 2 and the magnetic trends presented by King (1959). About 70% of the residual values lie within a ±40 gamma range. A high amplitude positive anomaly (A on Fig. 2), located in the north-central portion of the county, probably extends into Bradford County to the north. The positive anomaly is flanked on both sides by negative anomalies which trend northeasterly in accordance with King's regional trends. The northwestern region of Alachua County is occupied by a large negative anomaly (B). West of anomaly B, relative intensity values again begin to increase, suggesting a possible positive anomaly in Union and Columbia counties to the north. Two smaller negative anomalies (C and D) occupy an elongated magnetic trough which flanks anomaly A to the southeast.

The southern portion of the residual anomaly map has few features. Several small positive anomalies exist in the south-central portion of the county, and another small negative anomaly is in the southeast corner.

A comparison of Fig. 2 with the Bouguer gravity anomaly map for Alachua County presented by Smith and Taylor (1977) reveals several similarities. The most striking of these is the northeast alignment of a negative gravity anomaly in the northwest region of the county, corresponding to the magnetic trend in the same area. Barnett (1975) proposes a northeasterly trending graben in the sub-Zuni (pre-Mesozoic) basement, which is perhaps conterminous with the existence of a much larger Triassic graben beneath the Apalachicola region. Smith and Taylor (1977) suggest that the low gravity values in northwestern Alachua County may imply a greater thickness of low-density sedimentary rocks and a deeper basement. The Apalachicola graben is filled with red feldspathic and arkosic clastics and diabase dikes (Barnett, 1975). A northeasterly trending graben with a similar stratigraphy lying northwest of anomaly B is a possible explanation for the high magnetic anomalies and low gravity anomalies. The absence of a corresponding anomaly on Smith and Taylor's (1977) gravity map with the positive anomaly labeled A (Fig. 2) is also apparent.

Breiner (1973) presented qualitative geometrical patterns for magnetic anomalies which result from variously-shaped sources. Figure 3A is a cross-section of magnetic anomalies A and B along line S-S' of Fig. 2. Anomaly B, in profile, seems superimposed over the western edge of anomaly A. The form of anomaly B closely resembles Breiner's model for a fault involving two rock units of different magnetic susceptibilities. Anomaly A, in north-central Alachua County, has an amplitude of approximately 120 gammas. It is similar in shape to Breiner's representations of a dike (vertical sheet) or a narrow intrusive (vertical cylinder).

A model which may account for magnetic anomaly A is a vertical cylinder with 0.6km^3 volume, buried at 1.5 km beneath the surface. This configuration produces a magnetic anomaly of 120 gammas amplitude for a magnetic susceptibility within the range of an average diabase containing 4% magnetite. Drill hole data for Alachua County are sparse. Milton (1972) lists no wells in Alachua County, but presents data for surrounding counties. Diabase, which intruded black shale, was encountered in Columbia County (north of Alachua County) at about 1,066 m from the surface. In Levy County (southwest of Alachua County), diabase was encountered at 1,313 m below the surface in lower Paleozoic quartzite and shale. In Putnam (east) and Marion (south) counties, volcanic ash and rhyolite were encountered at 1,180 m and 1,413 m from the surface, respectively (Milton, 1972).

Based on half-width rules described by Breiner (1973), the maximum depth to the anomaly source may be estimated as 5 km. Drill hole data reveals the Paleozoic Tippecanoe sequence at 750 m and 960 m beneath the surface in Alachua County (Barnett 1975). R. A. Johnson (pers. comm., 1978) has interpreted electric

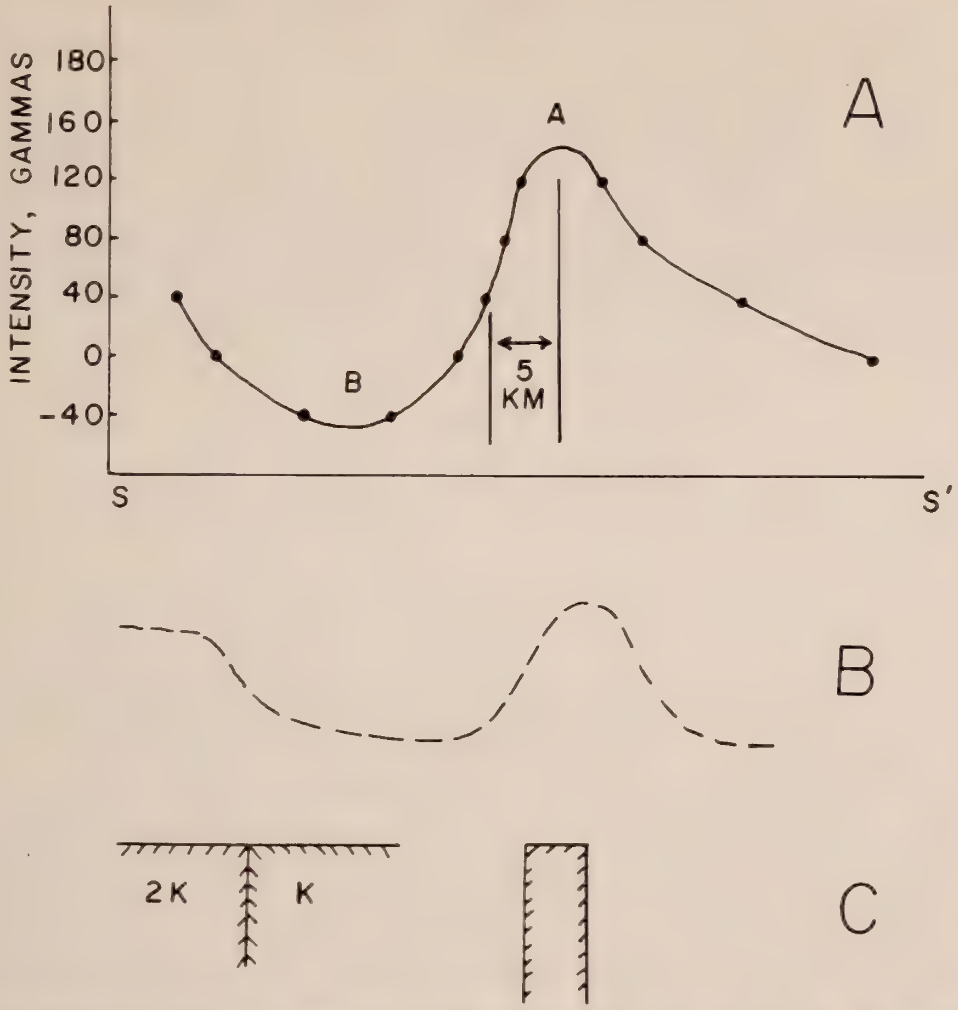

FIG. 3. (a) Residual magnetic anomaly profile along line S-S' of Fig. 2. (b) Theoretical mag- etic anomaly profile resulting from (c) fault juxtaposing two rock types of different magnetic sus- eptibilities (K and 2K), and vertical cylinder of high magnetic susceptibility.

nd gamma logs of the Deerhaven test hole in Alachua County to indicate the retaceous-Paleozoic boundary is at approximately 1,000 m deep, although a harp contrast in the logs occurs at 800 m. Wicker and Smith (1978) estimate he thickness of the Tippecanoe sedimentary rocks as 1.5 km. It is quite possible hat undulations in the buried erosional surface of the magnetic basement rocks re the source of the various magnetic anomalies and no graben structures need e invoked to account for them.

CONCLUSIONS—This investigation augments the present statewide magnetic nomaly map of King (1959) with increased detail and fine structure. Corrected ield values of the absolute magnetic intensity measured in early 1978 varied rom 50,067-51,035 gammas in Alachua County. The regional gradients on an somagnetic map demonstrate a marked decrease in magnetic intensity values rom east to west. This may reflect a westerly dip of magnetic basement materials hich form the Peninsular Arch. Residual magnetic anomalies determined by emoving a computer-derived regional trend surface may be interpreted to uggest: (1) the existence of a northeasterly-trending graben beneath the north- estern corner of Alachua County, and (2) the possibility that diabase dikes ie beneath the northern portions of the county. The anomalies may also be ttributed to high local relief on the subsurface of the Paleozoic rocks. Continuing studies at the University of Florida by the Geophysical Laboratory are planned in Union, Bradford, and Columbia counties.

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Environmental Sciences

HEAVY METAL DISTRIBUTION IN BISCAYNE BAY SEDIMENTS

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Abstract: *The hypothesis that the environmental condition of the north Biscayne Bay is polluted, while the south bay is relatively clean, was examined by studying the distribution of cadmium, lead, mercury and zinc in the bottom sediments. Samples were collected from a primary study area in the generally accepted boundary between north and south bay and from sample sites along the Intracoastal Waterway. No significant difference was found in the concentrations of the subject heavy metals in the north and south bay.*[*]

Estuaries and tidal lagoons are an important link in the environmental system and are particularly susceptible to the influence of man's activities

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(McHarg, 1971; McPherson, 1976). Biscayne Bay, Dade County, Florida, is one such productive marine resource that provides breeding and nursery areas vital to the fisheries of the area (Wanless, 1976). The bay is also an important part of the social, economic and cultural life of Dade County in that it provides recreational opportunities, commercial opportunities and aesthetic values. However, much of the local community tends to view the bay as 2 distinct systems; the area north of the Rickenbacker Causeway is considered highly polluted while the area south of the causeway is considered relatively unpolluted (Bilhorn, 1975). In addition, statements by local officials tend to indicate that this view is accepted by the scientific community (Todd, 1975; Waite, 1976). With the appropriation of $250,000 by the Florida Legislature for a study of means to restore the bay, an investigation to confirm or refute the prevailing belief is timely.

As an initial study of the environmental quality of the bay, sediment samples were tested for the storm runoff related metals cadmium, lead, mercury and zinc. The input level of these metals is reflected in their concentration in the sediments (Windom, 1976). The study area was centered on the commonly accepted boundary between the north and south bay. Additional samples were collected outside the primary study area along the Intracoastal Waterway. The mean concentrations between the north and south study area are compared and, in addition, localized high readings are discussed in relation to the physiographic features of the bay.

METHODOLOGY—Sediment samples were collected from a primary study area straddling the Rickenbacker Causeway and from points on the Intracoastal Waterway from the extreme north bay to the extreme south bay. The study area is bounded on the north by Government Cut and on the south by a line from the Coral Gables Waterway to Cape Florida (see Fig. 1). Because the Rickenbacker Causeway is the commonly accepted boundary between north and south bay (Prestamo and Greenan, 1976; Waite, 1976), and the north area is mostly enclosed and circulation constricted, the levels of the subject metals should be higher in the north area. The Intracoastal Waterway is a dredged channel from north to south approximately bisecting the bay. The primary advantage of using the Waterway is the ease of locating sample points in open water.

Sediment samples were collected from a boat using a Ponar dredge and thus, only recent sediments were tested. The top 2-3 cm. of sediment collected in the dredge were placed in sterilized, pre-sealed plastic bags. In the laboratory, the samples were placed in separate porcelain crucibles, air-dried at 60°C for 12 hr., then pulverized and stored in glass jars until pre-analysis chemical treatment (Van Loon, et al., 1973; Richins and Risser, 1975). All analyses were performed on a Perkin-Elmer Model 503 Atomic Absorption Spectrophotometer with a Model 56 Recorder. Lead, cadmium, and zinc were measured according to the Perkin-Elmer instruction manual and mercury was measured by the cold vapor apparatus supplied by Perkin-Elmer.

RESULTS—The means of the sediment samples collected from sites north and south of the Rickenbacker Causeway were tested for a significant difference using

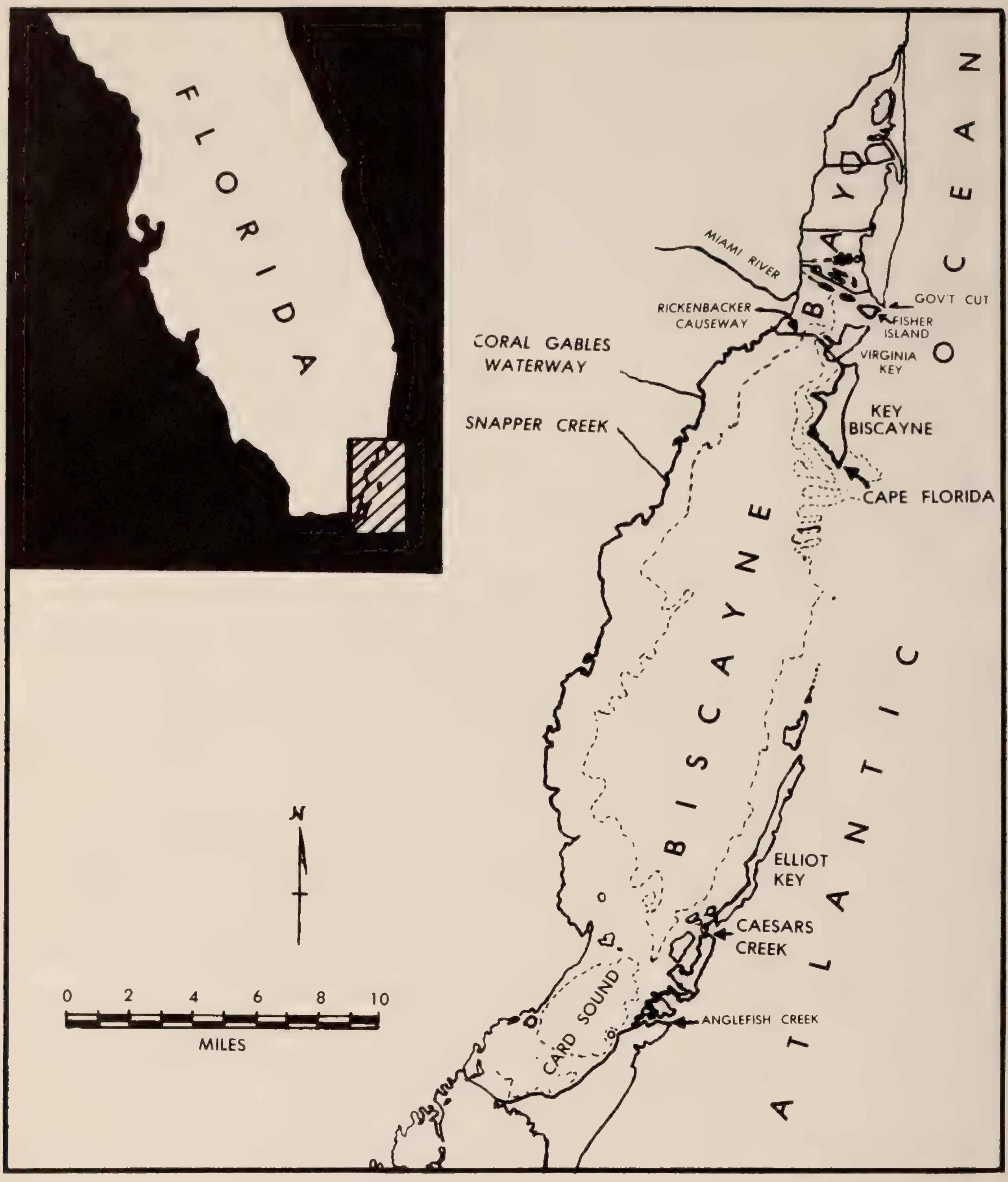

Fig. 1. Biscayne Bay and Card Sound. Adapted from Lee and Rooth (1973).

the STAT 03 programs of the Florida International University UNIVAC 1108 computer. In no case was there a statistically significant difference. This finding is counter-intuitive because of the development in the north study area and the discharge from the Miami River.

Samples collected from 3 sites in the east bay, between the Miami River and the Rickenbacker Causeway, showed lead and zinc concentrations 2 to 3 times the concentrations in other north study area samples. This is one of the receptor areas for discharge from the Miami River and also receives runoff from the Rickenbacker Causeway, a heavily traveled link to Key Biscayne and the popular bathing area.

Samples were collected from 9 sites along the Intracoastal Waterway to obtain some indication of the change in concentrations of the heavy metals beyond the primary study area. The results of the sampling are in Figs. 2 and 3. With the exception of site M6, all samples were collected near navigation markers to facilitate mapping. Sites M1 to M4 are north of the Rickenbacker Causeway, while M5 to M9 are south.

Cadmium, lead and zinc concentrations were highest in the northernmost samples collected along the Intrascoastal Waterway. On the other hand, mercury seems to be slightly higher in the southern regions of the bay (see Figs. 2 and 3). The Rickenbacker Causeway is located between points M4 and M5.

Samples in the south study area were collected in December and from the north area in February. These months are in the dry season and are characterized by decreasing predominantly northeast wind. The water temperature dropped from an average of 36°C in December to an average of 20°C in February, while the respective mean air temperature measured at the Miami International Airport was 25°C and 19°C.

Marine life was found in one sample site just south of Cape Florida. Vegetation was collected at about half the sample sites, equally divided between north and south areas.

Of the 40 samples collected in the primary study area, 5 were replications and 6 were from sites close enough to be useful in evaluating consistency of results. The observations were essentially the same and within the expected variance for the metals in sediment. Only 2 comparison samples were collected for the Intracoastal Waterway at M4 and M6. The results of these samples also matched within the expected range.

DISCUSSION AND CONCLUSIONS—The primary conclusion of this study is that the distribution of the heavy metals cadmium, lead, mercury and zinc in the sediments of Biscayne Bay is not significantly different north or south of the Rickenbacker Causeway. The secondary conclusion of the study is that the distribution of the heavy metals does not support the belief that the north bay is polluted while the south bay is clean. The implications of these conclusions are discussed in the following sections.

There can be little doubt that the environment of Biscayne Bay has been drastically altered as a result of man's activities. Shoreline construction has created concrete bulkheads around most of the north bay and some of the south bay: dredging and filling activities have destroyed seagrasses and mangrove fringes: artificial canals discharge storm water runoff directly into the bay: and, causeways in the north bay reduce circulation and flushing. Where the damage is visibly obvious, through increased turbidity and reduced sport fishing yields, people perceive the problem and look for action from the local government and the scientific community. When the water is clear, and the shoreline relatively undeveloped, the problem is not as obvious and many citizens do not perceive the need for action. Thus, the belief in a clean south bay and a polluted north bay is reinforced.

On the contrary, the results reported in Table 1 do not support the belief that

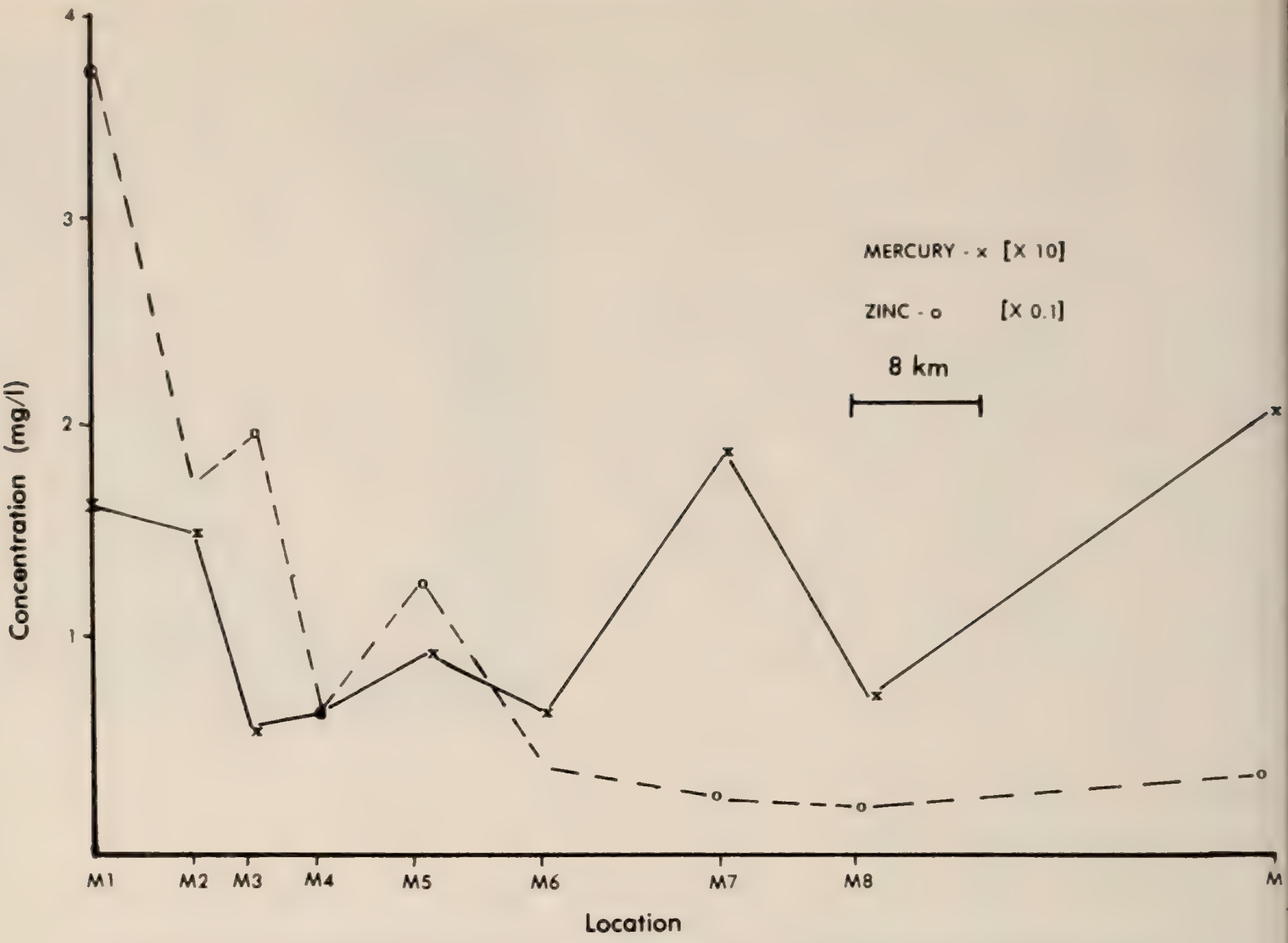

Fig. 2. Concentration of mercury and zinc from sites on the Intracoastal Waterway.

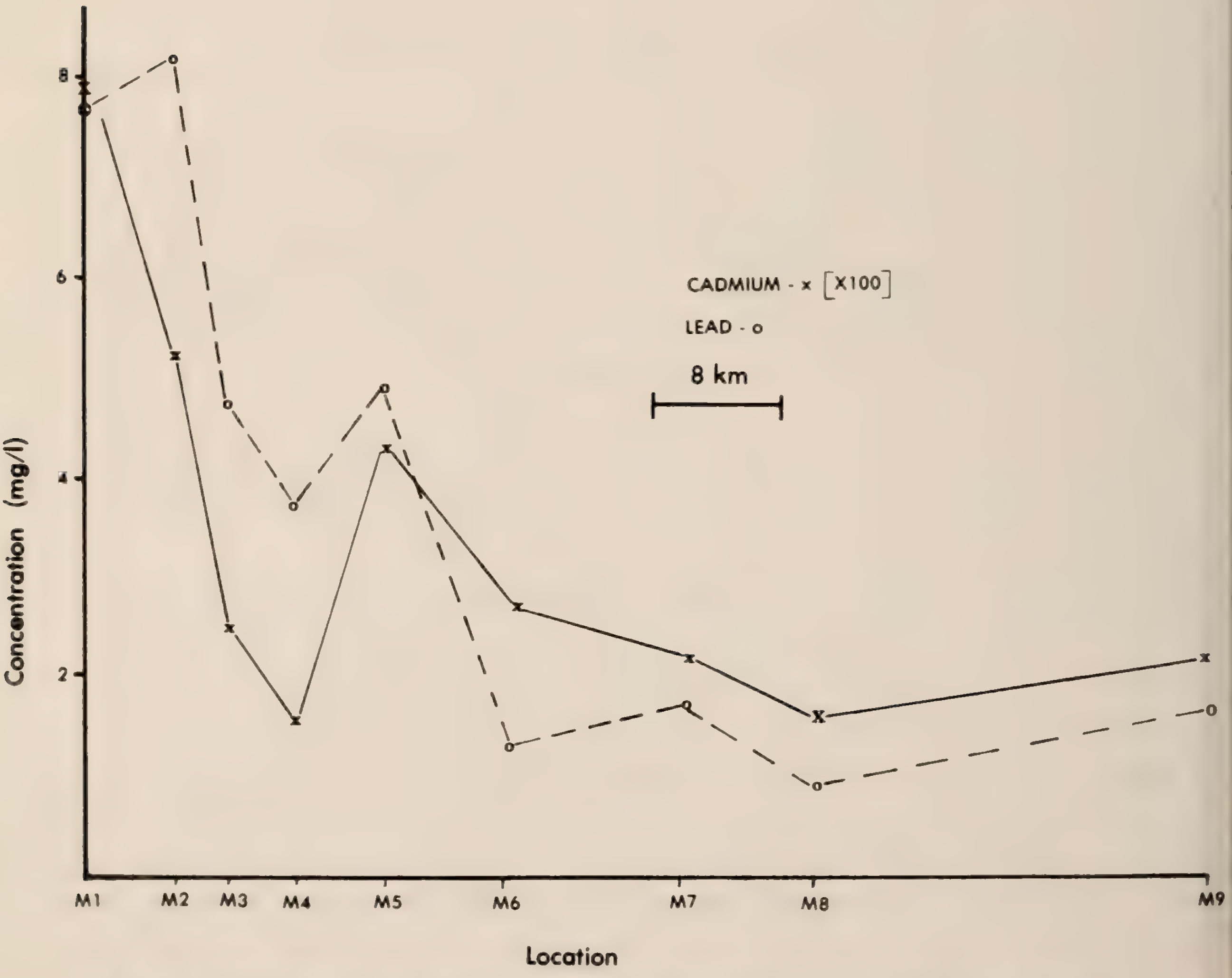

Fig. 3. Concentration of cadmium and lead from sites on the Intracoastal Waterway.

the north bay is of lower environmental quality than the south bay. Although large variations in the concentrations of the studied metals are noted, the mean concentration for cadmium, lead and mercury differ little north and south of the Rickenbacker Causeway. Although the mean concentration of zinc is larger, it is not a significant difference. The statistical analysis showed no significant difference between the mean concentrations north and south of the causeway.

Table 1. Concentration of heavy metals in sediment samples.

	North Area		South Area	
	Mean	n	Mean	n
Cadmium	.032* (.0012)	17	.033 (.00047)	23
Lead	3.18 (8.7)	17	2.06 (2.7)	23
Mercury	.109 (.011)	17	.138 (.023)	23
Zinc	19.8 (999.1)	17	7.6 (33.6)	22

*All values in mg/1; variance in parentheses.

In addition to the above, the sampling along the Intracoastal Waterway tends to support the hypothesis that the environmental conditions of the north and south bay are approximately equal. While cadmium, lead and zinc do have higher concentrations in the far north area, this is not consistently true for all sample points. Mercury in particular is higher in the south bay and several of the cadmium samples are higher than some north bay samples. In no case are the differences in metal concentrations of the samples major. Thus, there is no evidence to support a conclusion of significantly higher concentrations of heavy metals in the north bay. Because these metals are associated in many cases with the fine particles, and are most likely carried by storm water runoff, it is not unreasonable to assume that other pollutants are similarly distributed.

The sediments of estuarine areas can be expected to contain significant amounts of heavy metal pollutants. Runoff from developed areas and point source discharges introduce substantial loadings. Analysis of samples from Biscayne Bay indicates the bay is less polluted than many industrialized estuaries studied by Windom (1976).

Acknowledgments—The research was funded by a grant from the FAU-FIU Joint Center for Environmental and Urban Problems.

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Florida Sci. 42(4):242-248. 1979.

DISTRIBUTIONAL NOTES ON SOME LOWER MISSISSIPPI RIVER FISHES—*Vincent Guillory*, Florida Game and Fresh Water Fish Commission, P. O. Box 1903, Eustis, Florida 32726[1]

ABSTRACT: *Three fishes were collected for the first time in Louisiana during recent ecological investigations in the Mississippi River. The known ranges of* Hybopsis gelida, H. meekei *and* Noturus flavus *were extended 1125, 642, and 370 river km, respectively.**

INTENSIVE field collection of fishes were recently made in the lower Mississippi River by Louisiana State University (Guillory, 1974) and Woodward-Invicon (Bill McConnel, pers. comm.) personnel near St. Francisville, Louisiana and Grand Gulf, Mississippi, respectively. These studies, located at proposed nuclear power sites, were initiated to satisfy the requirements of the National Environmental Policy Act. I report on several species (*Hybopsis gelida, H. meekei, Noturus flavus*) collected during the course of these studies which were unknown from Louisiana (Douglas, 1974).

RESULTS AND DISCUSSION—Two juvenile *Hybopsis gelida* (Girard) were collected by seine in the Mississippi River on the west side of Fancy Point Towhead below St. Francisville, Louisiana, on 30 January, 1973 by Guillory (1974). *Hybopsis gelida*, a characteristic species of the upper and middle Missouri River drainage, inhabits the main channels of large silty rivers and is most often found in swift current over gravel (Bailey and Allum, 1962). In the Mississippi River *H. gelida* is very rare and normally is restricted to that portion between the mouths of the Ohio and Missouri rivers (Pflieger, 1971; Smith et al., 1971). The record of *H. gelida* extended its range approximately 1,125 river km from its previous southern-most locality in the Mississippi River at Cairo, Illinois (Bailey and Allum, 1962).

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[1] Contribution no. 66 of the Eustis Fisheries Research Laboratory.

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Personnel of Woodward-Invicon collected 3 specimens of *Hybopsis meekei* Jordon and Evermann from the Mississippi River during the spring of 1973. Two individuals were taken from the intake screens of the Vicksburg Power Plant and one by otter trawl from Grand Gulf, Mississippi (Bill McConnel, pers. comm.). *Hybopsis meekei*, known only from the main channels of the Missouri River, lower Kansas River, and the Mississippi River between the mouths of the Ohio and Missouri Rivers, inhabits sand or gravel bottoms in deep, swift water (Bailey and Allum, 1962). This species is uncommon in the Mississippi River (Smith et al., 1971). The records from the lower Mississippi River at Vicksburg and Grand Gulf extend its range 642 river km.

A single specimen of *Noturus flavus* was collected in the Mississippi River at Grand Gulf in a hoop net during the spring of 1973 by Woodward-Invicon personnel. Taylor (1969) indicated *N. flavus* occurs as far south in the Mississippi River as the mouth of the Ohio River and prefers riffles or rapids of moderate or large streams. Buchanan (1973) later collected one *N. flavus* from the Mississippi River in Phillips County, Arkansas on 1 April 1971. The range of *N. flavus* was extended 370 river km by the record at Grand Gulf.

In addition to these records, other species with northern affinities have been collected in the lower Mississippi River. Cook (1959) cited records of *Ichthymyzon unicuspis* near Palymyra Island south of Vicksburg, Mississippi in 1937 and *Acipenser fulvescens* from Grand Gulf, Mississippi in 1950; these localities were 700 and 520 river km, respectively, downstream from the nearest known records in the Mississippi River.

This paper emphasizes the lack of fish collections from the lower Mississippi River prior to the 1970's. Even today, it appears that little more than cursory appreciation of the ichthyofauna has been accomplished. Additional surveys are needed in the Mississippi River, as well as most larger rivers in the South.

ACKNOWLEDGMENTS—Special thanks are extended to John Conner for his help in collecting *Hybopsis gelida* and Bill McConnel for his permission to cite species collected by Woodward-Invicon personnel.

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Florida Sci. 42(4):248-250. 1979.

ON THE IDENTITY OF *KINOSTERNON PUNCTATUM* GRAY 1855—

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Abstract: Kinosternon punctatum *Gray is a junior synonym of* Kinosternon subrubrum subrubrum *(Lacépède), not* Kinosternon subrubrum steindachneri *(Siebenrock) as the type locality suggests.*[*]

Kinosternon punctatum was described by John E. Gray in 1855, based on a single small juvenile collected by E. Doubleday in "East Florida". Although Gray (1870:67) later believed this specimen was synonymous with LeConte's (1854) *K. sonoriense*, Boulenger (1889) and all later authors accurately recognized *K. punctatum* as a junior synonym of *K. subrubrum* (Lacépède 1788:618). However, 2 subspecies of *K. subrubrum* (*K. s. subrubrum* and *K. s. steindachneri)* intergrade in northeast Florida (Ernst et al., 1974). Because the possibility thus existed that *K. punctatum* Gray 1855 might be a senior synonym of *K. steindachneri* Siebenrock (1906:727), I examined the holotype.

The type [British Mus. Nat. Hist. 1946.1.22.30; figured in plate XXC, of Gray (1870)], a juvenile of 22 mm plastron length, was in very poor condition; it had become almost completely disarticulated and nearly unidentifiable in its alcohol. Based solely on visual examination, I was unable to determine if the holotype represented *K. subrubrum steindachneri* or the nominate subspecies. Identification was possible only by examination of scute measurements.

Previous analysis of morphometric data from specimens of the subspecies *K. s. subrubrum* and *K. s. steindachneri* indicated that the character proportions bridge length/plastron length (BL/PL) and bridge length/interabdominal seam length (BL/AB) would distinguish them (Table 1). Comparison of measurements from the holotype and Gray's figure of the type revealed that it falls within the range of variation of the nominate subspecies, and well outside that of *K. s. steindachneri. Kinosternon punctatum* Gray must therefore remain a junior synonym of *K. subrubrum subrubrum* (Lacépède).

Acknowledgements—I acknowledge the loan of specimens and information from Walter Auffenberg of the Florida State Museum (FSM), J. W. Gibbons of the Savannah River Ecology Laboratory (SREL), and R. Crombie and W. R. Heyer of the United States National Museum (USNM). A. G. C. Grandison and A. F. Stimson graciously loaned the British Museum (BMNH) holotype.

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TABLE 1. Characters useful in distinguishing *Kinosternon subrubrum subrubrum* and *K. subrubrum steindachneri* ($\leq$ 25 mm PL). Measurements from the holotype of *K. punctatum* and from the only illustration of the specimen are included. Means ± one standard deviation appear above the range.

	N	PL	AB	BL	% BL/PL	% BL/AB
K. s. steindachneri[1]	9	21.0 (19.2-24.0)	5.08 ± 0.54 (4.4-5.9)	2.41 ± 0.14 (2.3-2.7)	11.5 ± 0.6 (10.2-12.3)	47.6 ± 3.8 (41.5-54.0)
K. punctatum						
Measurements from holotype	1	22.0	5.6	between 3.3 & 3.6	between 15 & 16	between 59 & 64
Measurements from Gray 1870, plate XXC	1	---	---	---	19.5	71.8
K. s. subrubrum[2]	10	19.9 (15.1-24.2)	5.17 ± 1.14 (3.7-6.7)	3.04 ± 0.70 (2.0-4.9)	15.1 ± 1.2 (13.2-16.6)	58.6 ± 2.6 (54.1-63.0)

[1] Specimens FSM or personal collection from Alachua Co. or southward in Florida.

[2] FSM, SREL, and USNM specimens from Alabama, Georgia, Maryland, South Carolina, and Virginia.

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Florida Sci. 42(4):250-252. 1979.

XANTHIC SPECIMENS OF THE SPECKLED HIND, *EPINEPHELUS DRUMMONDHAYI* (SERRANIDAE), FROM THE EASTERN GULF OF MEXICO—*Gregory B. Smith and Lewis H. Bullock*, Florida Department of Natural Resources Marine Research Laboratory, 100 Eighth Avenue S. E., St. Petersburg, Florida 33701

Abstract: *Xanthic specimens of the speckled hind* (Epinephelus drummondhayi) *are described from the eastern Gulf of Mexico.**

A xanthic individual of *Epinephelus drummondhayi* was captured during June 1978 southwest (220°) of Tampa Bay, Florida in 46 m of water. The fish was hook-and-lined by Bennie Keigans, a commercial fisherman aboard the DONNA-G. The specimen was delivered on ice to the Florida Department of Natural Resources Marine Research Laboratory (FSBC) where 35 mm color transparencies of the fish were taken immediately.

Smith (1971:75) realized that "xanthic individuals occur in several [grouper] species with considerable frequency and that some grouper names are based upon these yellow variants which are probably the result of a single recessive gene." He commented on xanthic specimens of the coney (*Epinephelus fulvus)* in which the entire fish is a bright chrome yellow. Smith (1976) sighted 4 xanthic specimens of *E. fulvus* at deep-water (> 30 m) reefs in the eastern Gulf of Mexico. Moe (1963) described partial albinism in a xanthic specimen of the red grouper (*E. morio)* from the eastern Gulf. The present note constitutes the first published Gulf of Mexico record of xanthism in *E. drummondhayi.*

Except for coloration, this specimen (FSBC 10981; 197 mm SL) agrees with Smith's (1971) description of *E. drummondhayi.* Meristics are as follows: D. XI, 16; A. III, 9; P. 17; total gill rakers 26.

Instead of the typical coloration described by Smith (1971), the xanthic specimen was almost entirely yellow with bluish-white spots (of approximately equal size) distributed over the head, body and median fins. The pelvic, soft dorsal, caudal, and anal fins were reddish on the distal third. The distal margin of the spinous dorsal was edged in black; spines IV through X had whitish blotches on their postero-distal borders. The inside of the mouth was white with yellow on the pterygoid area, corners of the mouth, and between the lower teeth and posterior half of the lower lip. The region including the ceratohyals, tongue, gill arches and rakers was yellow. The stomach was empty. Gonads were undeveloped.

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Examination of *E. drummondhayi* specimens in the Marine Research Laboratory collection revealed another xanthic individual (FSBC 2732; 250 mm SL). Although its color was faded, field notes taken at capture indicated that this specimen was similar to the one described above.

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Florida Sci. 42(4):252-253. 1979.

A POSSIBLE EXPLANATION FOR THE ABSENCE OF ENDEMIC FISHES IN LOUISIANA

—*Vincent Guillory*, Florida Game and Fresh Water Fish Commission, P. O. Box 1903, Eustis, Florida 32726

Abstract: *The absence of endemic Louisiana fishes may be attributed to historical and physiographic factors. The periodic inundation of the Mississippi Embayment by the Gulf of Mexico during early Pleistocene interglacial periods obliterated the freshwater ichthyofauna. Afterwards, the ample dispersal mechanisms available prevented isolation and subsequent speciation of fishes in Louisiana.*[*]

There are no known endemic fishes in Louisiana. This is in contrast to neighboring areas of high endemism and differentiation, such as southwest Texas, the Ozarks, and the Mobile Basin (Hubbs, 1957; Pflieger, 1971; Ramsey, 1965).

There are several interrelated historical and physiographic factors which contribute to the absence of endemic Louisiana fishes: periodic inundation of the Mississippi Embayment by Pleistocene seas; paucity of springs; the location of Louisiana below the fall line; and the presence of very large rivers, especially the Mississippi River.

The ecological conditions at the time of differentiation of most present day species must be considered as a factor affecting endemism. Periodic inundations of the Mississippi Embayment by the Gulf of Mexico during Pleistocene interglacial periods as late as the Wicomico and Penholoway extended up the present Mississippi Valley as far north as Tennessee (Cook, 1966). Obviously, these salt water inundations decimated populations of freshwater fishes in Louisiana. Clench and Turner (1956) concluded that the inundation of streams by rises in sea level during the Pleistocene was responsible for the low incidence of endemism of mollusks in certain coastal streams, whereas those streams with headwaters which remained above sea level contained endemic species. It is not surprising that regions adjacent to the Mississippi Embayment not completely inundated are very important centers of differentiation and endemism; these areas include the Mobile Basin, southwest Texas, and the Ozarks. This inundation by the Pleistocene seas was probably the most important factor explaining the absence of endemic fishes in Louisiana.

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While the majority of extant species in the United States originated in the early Pleistocene, and the time span since the Pleistocene is usually associated with the differentiation of subspecies, speciation may occur in a few thousand years in isolated springs or other aquatic habitats (Miller, 1961). Caldwell (1965) suggested that springs of the southeastern United States may serve as places for relicism and endemism, as does those of the desert southwest (Hubbs and Miller, 1948). There are, however, very few springs in Louisiana.

There may have been adequate time for fishes to speciate in Louisiana since the retreat of the inland sea from the Mississippi Embayment; however, the ample dispersal mechanisms available to fishes due to Louisiana's location below the fall line and the presence of large rivers precluded any opportunities for the isolation of stocks and subsequent speciation.

The fall line marks a distinctive break in both geology and biota. There is a higher frequency of endemic species above the fall line as below (Ramsey, 1965). There are fewer endemic species on the coastal plain as compared to above the fall line because there are more opportunities for dispersal on the coastal plain. Fishes found above the fall line may be dispersed only by stream piracy, whereas fishes found below the fall line may expand their ranges via stream capture, swampy connections across low, poorly divided drainages, low salinity complexes between adjacent river systems, and tributary hopping along large rivers.

Large rivers, such as the Mississippi, are very important avenues of dispersal. Barriers to the dispersal of fishes inhabiting large rivers (including both typical riverine species as well as tributary species tolerating riverine habitats) are virtually non-existent (Metcalf, 1966). In addition, tributary species which normally avoid the Mississippi River, or other large rivers, may move from one habitable tributary to the next via the main channel; this process was termed "tributary hopping" by Metcalf (1966). One type of tributary hopping involves a deliberate behavioral mechanism; that is, a brief annual excursion of small stream fishes into large rivers (Bailey and Allum, 1962; Metcalf, 1966). Guillory (1974) indicated that the annual occurrence of *Notropis longirostris* in the Mississippi River was illustrative of this process. Perhaps more important than the foregoing in dispersal of fishes via large rivers is the occurrence of "waif immigrants" (Bailey and Taylor, 1950), or floodborne stragglers in the main channel. During the spring flood of 1973, Guillory (1974) collected 23 species in the Mississippi River which were normally restricted to floodplain swamps and/or upland tributaries.

In conclusion, the region encompassed by Louisiana's political boundaries is not an important center of ichthyofaunal evolution. Rather, this area is at or near the endpoint of recent waves of invasion from several zoogeographically distinct centers: the southwest, the Ozarks, the Mobile Basin, and various preglacial drainages of the Mississippi River. The lack of ichthyofaunal differentiation in Louisiana is due to two primary reasons. First, periodic inundation of the Mississippi Embayment by the Gulf of Mexico during early Pleistocene interglacial periods obliterated the freshwater ichthyofauna. Second, the numerous dispersal mechanisms available to fishes on the coastal plain prevented the isolation of localized populations (and subsequent speciation) in a single drainage after the retreat of the inland sea from the Mississippi Embayment.

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A THIRD OCCURRENCE OF THE INTRODUCED ATYID SHRIMP, *POTIMIRIM POTIMIRIM*, IN FLORIDA—*J. Thomas Beck*, Department of Biological Science, Florida State University, Tallahassee, Florida 32306

ABSTRACT: *Range of the introduced Brazilian shrimp is extended 190 km northward to Volusia County.*[*]

THE Brazilian shrimp (*Potimirim potimirim*) has been reported in drainage canals near Jupiter in Palm Beach County (Abèle, 1972) and about 100 km northward in Vero Beach in Indian River County (Gore et al., 1978). I report herein a third occurrence of *P. potimirim* in Florida in Reed Canal at State Road 5A in Daytona Beach (Volusia County). This location is about 190 km north of the above Vero Beach site. The one specimen was a male, 13.1 mm in total length, and was collected 11 December 1963, by W. Beck, Florida A & M University. At the same site other freshwater shrimps, *Palaemonetes paludosus* and juvenile *Macrobrachium* sp. were collected.

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